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Intellectual, Scientific, and Educational Influences on Sustainability Research

Rosario Adapon Turvey and Sreekumari Kurissery

Intellectual, Scientific, and Educational Influences on Sustainability Research

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Major developments have been achieved in advancing sustainability research in sustainability science (SS) as a new and distinct field. Based on its emerging academic landscape, SS has now acquired an unusual geographic footprint with a giant cluster of co-authorships in cities and countries at very different levels, all in pursuit of sustainable development and sustainability. It has gained a robust inclusion in the agendas of governments and corporations along with the burgeoning growth of educational and research programs worldwide. In the call for the integration of research and education, higher educational and research institutions have fostered the goals toward sustainability to address the practical protection of Earth's key support systems, climate change, and other global issues. In confronting a wide range of global issues in the 21st century, scientists across the globe see the need for accelerating knowledge in sustainability wherein knowledge production itself must be made sustainable.

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The term "endophyte" comes from words "endo" meaning within and "phyton" meaning plant. In 1866, De Bary first defined an endophyte as any organism that resides in the tissues of plants but not causing any harm. Thus, endophytes can be a microorganism, usually fungi or bacteria, that colonizes plants parts. The plant tissues/parts where endophytes grow include healthy leaves, petioles, stems, twigs, bark, roots, fruits, flowers, and seeds. They are found virtually in every one of the 300,000 species of vascular plants. Many endophytes co-exist in a single plant host with their populations ranging from one to hundreds of bacterial/fungal species. This chapter outlines a historical perspective of endophytes including ethnobotanical approach to drug discovery. Also, this chapter provides upto date information on the emerging role of endophytes in the sustainability of pasture and economy of agriculture, thereby contributing to the environmental sustainability.

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Zimbabwe is a semi-arid country reliant on regular rains (November-April). Mean annual rainfall is low, and many rivers in the drier parts of the country are not perennial. In the small-scale horticultural sector, irrigation becomes handy. Rainfall exhibits spatial and temporal variability. This scenario is characterized by shifts in the onset of rains, increases in frequency and intensity of heavy rainfall events, increases in the proportion of low rainfall years, decreases in low-intensity rainfall events, and increases in the frequency and intensity of mid-season dry spells. Drought have increased in frequency and intensity. Agriculture is the main source of income for most smallholder farmers who depend on rain-fed cropping and livestock rearing. Adaptation of agriculture to climate variability and change impacts is vital for livelihood. To develop appropriate strategies and institutional responses to climate change adaptation, a clear understanding of climate change impacts on smallholder farmers at farm-level is vital.

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Global warming is unequivocal and almost certainly caused by recent human activities that have increased the greenhouse gas (GHG) emissions. Emissions reductions of carbon dioxide and cumulative carbon emissions from energy consumption have created widespread concern of various government agencies, scientific circle, and the general public. The states and the international community are simultaneously struggling to address climate change. Impacts of carbon emission are inevitable and there is a long debate as to who bears the losses incurred due to the carbon emission. Both the developing and the developed economies need to reduce their CO2 intensity significantly for stabilizing the Earth's climate at no more than a 2°C temperature rise. However, for the sake of health, safety, and environment, the supply of oil and gas as well as emission of carbon need to be operated in an environmentally sustainable manner so as to avoid environmental harms.

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Despite building a clear and compelling message about the importance of conserving biodiversity and what we risk in depleting it, meaningful engagement from implicated stakeholders remains limited. Past studies have examined the gap between the possession of environmental knowledge and displaying behavior that would help to conserve it. Essentially, increasing awareness and interest in environmental issues does not ensure that individuals will make the necessary changes in behaviours detrimental to biological conservation. This is a concern as failure to meaningfully engage the public into acting on conservation strategies will hamper efforts to curb biodiversity loss. Herein the authors investigate why action to address biodiversity loss has been slow or deficient in many jurisdictions. The authors draw from models and theories developed in health and social sciences to provide context to the key factors that prevent action and propose steps that could be taken to stimulate it.

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Educating for a sustainable future and learning to live within our planetary limits is the most pressing challenge of our times. In this chapter, the authors present an emerging model of transcultural education that brings together Indigenous and western knowledges. This approach aims to engage learners from different cultures and knowledge traditions with the purpose of guiding them through ideas and processes of imagining, listening, speaking, and working together in a way that respects differences, acknowledges common ground, and seeks to co-create new knowledges. Bringing together Indigenous and Western knowledges in this manner creates a unique context that can potentially build the mindsets, skills, and dispositions that are needed for living and managing sustainably. A pedagogy grounded in this approach can potentially promote student interest and engagement across cultural and social divides, foster successful learning about bridging social inequalities, and cultivate an ethos of social, cultural, and environmental responsibility.

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Only about 25% of the world's land area and soil can be viewed as sustainable for agriculture. The rest of the soils are too dry, too wet, steep, rocky, cold, shallow, acidic, alkaline, or saline to allow the growing of crops. The major problems lie on the harshly increasing need for agricultural products due to rising populations as well as to the world desire to attain ever higher living standards. Food shortage, increase in toxic chemical in production, and urbanization are three inseparable things. One way to solve food shortage is to increase agricultural production. However, increase of agricultural production involves a package of measures that must be fitted to the specific situations in each case. Those measures are the use of high-yielding crops like cassava and varieties and a set of treatments designed to optimize growing conditions. Among such treatments is the use of nature-based solution like the use of cassava waste in feeding of livestock, use of cassava waste as a manure, minimizing losses of water and nutrients due to runoffs.

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In theory, there is a strong, two-way relationship between sustainability research and public policy that functions in synchrony to identify, understand, and ultimately address ecological problems for the greater good of society. In reality, such a cooperative relationship is rarely found. Instead, researchers and policymakers face a suite of challenges that prevent effective communication and collaborative pursuits, prolonging the period required to address environmental issues. In this chapter, the authors apply a novel interdisciplinary approach to identify key barriers and solutions to translating research into policy. In doing so, the authors present two separate discussions focused on the natural and social sciences. The authors also review established research-to-policy frameworks to develop the new "cohesive" framework. By addressing key barriers between researchers and policymakers, society will be better able to respond to the various environmental stressors that it faces today.

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This chapter is a review of scholarly works on planning for urban futures with special reference to sustainable cities. The chapter aims to produce an update of the challenges and current perspectives on urban planning, sustainability and development across the globe. As informed by research from the academic and scientific communities, the review provides the prospective directions and trends for securing a sustainable urban future. In the sustainable cities discourse, recent intellectual inquiry focused on the conceptualization and knowledge production to create sustainable cities. Though the scope of the review may not be exhaustive, the purpose is to articulate the current progress in the research front concerning concepts and definitions on sustainable cities, planning and methods for urban sustainability development and assessment. The ultimate goal is to provide local authorities, practitioners and/or city governments with some perspective and guidance in working towards urban sustainability in the future.

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Over the past century, sustainability scholars and scientists have largely focused on the complex relationships between society, economy, and environment. The authors refer to this approach as external sustainability research, which positions the built and natural environment as key to a sustainable future. Yet, our external environment is a manifestation of deeply held beliefs, values, attitudes, and perceptions of the world—the inner dimensions of sustainability. Within sustainability science, a deeper understanding of the inner dimensions could promote lasting external sustainability measures, strategies, and interventions. This chapter envisions sustainability as a holistic collection of internal and external guiding principles that can be enhanced through practice. First, the authors draw on perspectives from "Western sustainability" and Indigenous philosophies. Next, case studies integrating holistic sustainability approaches are shared. They conclude by integrating the primary literature with the case studies and call on sustainability science to more deeply consider the inner dimensions.

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This review chapter explores place-making in terms of how it is linked with sustainable community development (SCD). Place-making as it relates to sustainable community development has not been understood in the practice of sustainability, urban planning, and community development. Here, place-making is a process of planning, designing, managing, and programming spaces to create patterns and activities in cultural, social, economic, and ecological terms to achieve a better quality of life, a prosperous economy, and healthy environment. As informed by research, it can be an approach to sustainability thinking as a strategy for transforming cities and public spaces to promote well-being and prosperity in a local place, urban area, or neighborhood. In the long-term, the theory and practice of sustainable community development relative to place-making will evolve and eventually produce well-grounded meanings and conceptualizations as we engage in more research on sustainability and sustainable development.

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Preface

We are delighted to have the opportunity to publish this book: *Intellectual, Scientific, and Educational Influences on Sustainability Research* as an edited collection by IGI Global.

Our planet Earth and its life-support systems are in a state of constant change, largely due to systems and human interaction with physical, biological, geological and environmental processes. With pressing issues and challenges facing the 21st century society, it is important to seek solutions to major sustainability problems such as climate change, biodiversity loss, freshwater scarcity, land degradation and urban air pollution. One way to address them is to make progress in sustainability research. The goal of this book is primarily to bring the volume as an accessible edition of diverse topics by scholars doing sustainability research on contemporary problems in Sustainability Science (SS). SS has been referred to as an influential discipline and important subject of intellectual inquiry that deserves support from research, education and scientific inquiry from all over the world. A critical educational gap exists in educational resources and published books for use by students and researchers in Sustainability Science across the globe. This product is expected to provide an overview of the intellectual, scientific and educational influences in the new discipline. In this rapidly growing discipline, there are important research projects, pedagogical trends and academic interest that influence sustainability research.

The aim in publishing this book is to meet the crucial and unmet need in SS for research and reading sources given an academic gap on knowledge products on sustainability from intellectual, educational and scientific lens. From the outset, the book is envisaged as a resource for researchers, practitioners, students and academics pertaining to the current debates, innovative approaches and substantive studies in the science and practice of sustainability. A challenge to be addressed by this edited collection is to balance scholarship reflecting theory and practice in sustainability research given the fundamental demand for pedagogy, research and practice in SS. The volume aims to offer a highly accessible format with a wide range of concise and excellent Chapters with immense help to educate learners and students of SS.

This publication aims to be a valuable reference on current sustainability research topics for academics, researchers, practitioners, students and policy makers in the rapidly growing new discipline of Sustainability Science. Undoubtedly, there is a very wide subject area concerning SS which can be viewed from diverse perspectives. The idea is to get together the international, interdisciplinary, transdisciplinary and cross-sector collaboration in the context of the science of sustainability. With an objective for a dynamic global sustainability education, the edited volume hopes to be able to fill the crucial and unmet need for educational materials that integrates the theoretical foundations, methodological basis and practice in the science of sustainability. What is needed is an edited collection on research trends in SS to provide the current direction and focus of the new discipline, and the science for sustainability- to support through knowledge production, sustainability practices, policies and social transformation.

The target is to increase accessibility and use of scientific knowledge among academic and non-academic audiences as it assembles the wisdom and insights from up-to-date scholarship and advances in the new discipline of Sustainability Science. This volume aims to provide a highly accessible format with a wide range of concise and excellent Chapters, the scope of which could become an invaluable text for sustainability/sustainability science programs. The edited collection addresses the teaching and learning gaps by providing Chapters that offer a diverse set of research perspectives on intellectual, scientific and educational influences in sustainability research.

BOOK CHAPTERS

The book chapters include but are not limited to work that transcends intellectual boundaries between theory, concepts and conceptualization; methods and methodology; principles, practice and case studies in Sustainability Science. Chapter 1 covers major developments have been achieved in advancing sustainability research in Sustainability Science (SS) as a new and distinct field. Chapter 2 by Kurissery et al is concerned with a historic perspective of endophytes in vascular plants by examining its role in environmental sustainability. Endophytes can be microorganism's fungi or bacteria, that colonizes plants parts. Found virtually in every one of the 300,000 species of vascular plants, many endophytes co-exist in a single plant host with their populations ranging from one to hundreds of bacterial/ fungal species. This Chapter outlines a historical perspective of endophytes including ethnobotanical approach to drug discovery. It provides an up-to date information on the emerging role of endophytes in the sustainability of pasture and economy of agriculture thereby contributing to environmental sustainability.

The third *chapter* by Tanyanwiwa focuses on the impact of climate change and variability on small-scale peri-urban horticultural farmers in Domboshawa, Zimbabwe. The country is a semi-arid country reliant on regular rains (generally November to April). In the small- scale horticultural sector irrigation becomes handy as rainfall exhibits spatial and temporal variability. Agriculture is the main source of income for most smallholder farmers who depend on rain-fed cropping and livestock rearing in Zimbabwe. In order to develop appropriate strategies and institutional responses to climate change adaptation, a clear understanding of climate change impacts on smallholder farmers at farm-level is vital. Adaptation of agriculture to climate variability and change impacts is vital for livelihood. Chapter 4 by Chowdhury examines the reduction of carbon intensity whether a rhetoric or reality. Global warming is unequivocal and almost certainly caused by recent human activities that have increased the greenhouse gas (GHG) emissions. Emissions reductions of carbon dioxide and cumulative carbon emissions from energy consumption have created widespread concern of various government agencies, scientific circle, and the general public. Both the developing and the developed economies need to reduce their CO_2 intensity significantly for stabilizing the earth's climate at no more than a 2°C temperature rise to avoid environmental impacts.

Chapter 5 by Reyes et al explores biological conservation of which the authors raised the question if we can break the inertia. Past studies have noted the gap between the possession of environmental knowledge and displaying behavior that would help to conserve it. Increasing awareness and interest in environmental issues does not ensure that individuals will make the necessary changes in behaviours detrimental to biological conservation. The authors investigate why action to address biodiversity loss has been slow or deficient in many jurisdictions. The authors draw from models and theories developed in health and social sciences to provide context to the key factors that prevent action and propose steps that could be taken to stimulate it. Educating for a sustainable future and learning to live within our planetary limits is now the most pressing imperative of our times. In Chapter 6, Zohar and Newhouse present an emerging model of transcultural education that brings together Indigenous and Western knowledges. This approach aims to engage and learners from different cultures and knowledge traditions with the purpose of guiding them through ideas and processes of imagining, listening, speaking and working together in a way that respects differences, acknowledges common ground, and seeks to co-create new knowledges. Bringing together Indigenous and Western knowledges in this manner creates a unique context that can potentially build the mindsets, knowledges, skills and dispositions that are needed for living and managing sustainably in our challenging times.

In Chapter 7 by Onuoha, the topic on urbanization study its implications for sustainable development in a circular economy in particular food production. Only about twenty-five percent of the world's land area and soil can be viewed as sustainable for agriculture, the rest of soils are too dry, too wet, steep, rocky, cold, shallow, acidic, alkaline, or saline to allow the growing of crops. Food shortage, increase in toxic chemical in production and urbanization are three inseparable things. One way to solve food shortage is to increase agricultural production. However, increase of agricultural production involves a package of measures that must be fitted to the specific situations in each case. Those measures are: the use of high-yielding crops like cassava and varieties, and a set of treatments designed to optimize growing conditions. Among such treatments is the use of nature-based solution like the use of cassava waste in feeding of livestock, use of cassava waste as a manure, minimizing losses of water and nutrients due to runoffs. The authors of Chapter 8 (Dieleman et al) reviews the challenges turning the environment and sustainability science into policy. Researchers and policymakers face a suite of challenges that prevent effective communication and collaborative pursuits, prolonging the period required to address environmental issues. The authors apply a interdisciplinary approach to identify key barriers and solutions to translating research into policy. They present two separate discussions focused on the natural and social sciences and review research-to-policy frameworks to develop the new 'cohesive' framework. By addressing key barriers between researchers and policymakers, society will be better able to respond to the various environmental stressors that it faces today.

Chapter 9 by Turvey is a review of planning literature for framing urban futures with special reference to sustainable cities. The review provides the prospective directions and trends for securing a sustainable urban future wherein its purpose is to articulate the current progress in the research front concerning concepts and definitions on 'sustainable cities', planning and methods for urban sustainability development and assessment. The ultimate goal is to provide local authorities, practitioners and/or city governments with some perspective and guidance in working towards urban sustainability in the future. In Chapter 10, Bejarano et al explores the integration of inner and external dimensions for holistic sustainability. Within sustainability science, a deeper understanding of the inner dimensions could promote lasting external sustainability measures, strategies, and interventions. The Chapter envisions sustainability as a holistic collection of internal and external guiding principles that can be enhanced through practice. First, they draw on perspectives from "Western sustainability" and indigenous philosophies, then case studies integrating holistic sustainability approaches are shared. In Chapter 11, Turvey carries out a review of place-making in terms of how it is linked with sustainable community development (SCD). Place-making as it relates to sustainable community development has not been well understood in the practice of sustainability, urban planning and community development. In the long-term, the theory and practice of sustainable community development relative to place-making will evolve and eventually produce well-grounded meanings and conceptualizations as we engaged in more research on sustainability and sustainable development.

We hope that readers will find the contents relevant to those working in Sustainability Science or doing research and practice in sustainability and/or sustainable development. Finally, we hope this publication makes a key contribution to sustainability as part of the IGI-Global imprint.

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March 2019

Chapter 1
Advancing Sustainability Research in the 21st Century

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ABSTRACT

Major developments have been achieved in advancing sustainability research in sustainability science (SS) as a new and distinct field. Based on its emerging academic landscape, SS has now acquired an unusual geographic footprint with a giant cluster of co-authorships in cities and countries at very different levels, all in pursuit of sustainable development and sustainability. It has gained a robust inclusion in the agendas of governments and corporations along with the burgeoning growth of educational and research programs worldwide. In the call for the integration of research and education, higher educational and research institutions have fostered the goals toward sustainability to address the practical protection of Earth's key support systems, climate change, and other global issues. In confronting a wide range of global issues in the 21st century, scientists across the globe see the need for accelerating knowledge in sustainability wherein knowledge production itself must be made sustainable.

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OVERVIEW

This introductory Chapter provides a quick look at significant advancements in Sustainability Science (SS) as a new, inclusive, distinct field (Bettencourt and Kaur, 2011) that has sharply demonstrated productivity and potentially powerful impacts based on its remarkable growth in research, education and policy development. There are key milestones that deserved to be mentioned. Based on the report from the Proceedings of the National Academy of Sciences (PNAS), sustainability science has grown explosively since the late 1980s showing huge levels of scholarly collaboration and networking in research and education. In particular, the PNAS initiative has given SS an enviable position as a vibrant field of research and innovation with a 'room of its own' considering that it has developed a core research agenda as defined by the problems it addresses rather than by the disciplines engaged in intellectual inquiry as shown by the mounting flow of research results (NAS, 2007).

In this Chapter, the notable advancements in the global educational landscape of SS is termed here as 'sustainable knowledge capital' as a way to recognize the academic and societal contributions through sustainability research, education and knowledge production. In the past three decades, SS has also increasingly shown its pervasive and robust inclusion in the agendas of governments and corporations apart from the burgeoning growth of educational and research programs worldwide (Bettencourt & Kaur, 2011). In research and practice, the birth of SS has inspired researchers and scientists, stakeholders and practitioners across the globe to explore the application of theories, techniques and methods; find solutions to complex issues facing humanity and increase the Earth's capacity in dealing with human nature changes and challenges for tomorrow, today. At Harvard University Centre for International Development (CID), the goals of SS have been defined as one that advances the 'basic understanding of the dynamics of human-environment systems, to facilitate the design, implementation, and evaluation of practical interventions that promote sustainability in particular places and contexts; and to improve linkages between relevant research and innovation communities on the one hand, and relevant policy and management communities on the other (CID 2010; Frodeman, 2011).

Obtaining impetus from the progress in the academic landscape and societal interest, Sustainability Science has emerged in academia as a new science that examines the human-environment interactions and interconnections, socio-economic and environmental changes and complex challenges, and their impacts on the future of planetary life support systems over the last few decades (Shahadu, 2016). Since the 1980s, the academic literature has produced foundational publications such as *Our Common Future*, also known as the Brundtland Report by the United Nations' sponsored World Commission on Environment and Development (WCED, 1987). This report included the 'canonical definition' of sustainable development concerning intergenerational equity, futurity or posterity in the provision and use of resources on Earth. More importantly, the WCED publication paved the way toward worldwide interest on sustainability in terms of research, education and practice (Bettencourt & Kaur 2011; Kate 2011; Shahadu, 2016). The world would not be at this dynamic point of SS if we miss to acknowledge key figures such Lester Brown, a dynamic leader in the sustainability movement with the Wordwatch Institute (WWI) who is known to have done more to promote an understanding of sustainable development than anyone in the world. Not to forget several regular WWI publications such as the State of the World, 2013: Is Sustainability Still Possible? Based on published reports, there is a strong case or evidence for SS as a ‘young and fast-growing unified scientific practice of SS and bodes well for its future success some of humanity’s greatest scientific and societal challenges’ (Bettencourt & Kaur, 2011: 8).

In drawing and academic landscape, SS has acquired an unusual geographic footprint with its combined contributions and collaborations like the giant cluster of co-authorships in cities and nations at very different levels, all in pursuit of sustainable development and sustainability (Bettencourt and Kaur, 2011). Notably, valuable works have explored how SS has gained scholarly attention as a new scientific endeavour that has gained traction and established itself as an umbrella science for global sustainability (Kates, 2011; 2001; Komiyama & Takeuchi, 2006; Shahadu, 2016). The growth in academic research has been marked by this kind of widespread recognition of the need for, and importance of sustainability (Bettencourt & Kaur, 2011; Kates, 2011; Shahadu, 2016). A report on the body of global research for the period 2009-2013 registered a growth rate of publications at 7.6% double the Scopus average growth rate (Elsevier & SciDev.Net 2015). Further, an analysis of the publishing landscape in SS indicates that several journals have been launched with ‘sustainable’ and ‘sustainability’ attached to their journal titles contributing to an annual publication of more than 3,000 articles increasing linearly and exponentially from various authors across the globe (Kajikama et al., 2007). Such a launch of a variety of academic journals demonstrate the multidisciplinary nature of SS where there is academic and social demand.

Another interesting dimension is the creation of principal national research centers in many smaller universities and laboratories that have a presence in the field from countries like Australia, Netherlands, the UK, Canada and elsewhere (Bettencourt and Kaur, 2011, Wiek, 2011; Sanusi et al., 2013; Turvey, 2015). Though the scope of this Chapter is not entirely extensive, there are important advances (and concerns) associated with knowledge building for SS in the early 21st century that need to be mentioned such as the phenomenal rise of academic programs in much of the developed world from an institutional front of the academy.

MATTERS OF CONCERN

Despite some key successes, there are critical matters of concern to the academy in particular and the public in general. First, sustainability scientists have to overcome the reactive environmental paradigm and focus on the urgent and complex challenges that threaten the vitality and integrity of societies around the globe (Rayner 2011; 2012). Second, there are those who voiced concerns that rhetoric still outweighs the contributions toward achieving sustainability in a real-world context (Wiek et al., 2012). The point however is that grasping the current status of SS is more of an 'urgent task' as we move forward with sustainability research and knowledge production (Dovers, 1993; Kajikawa et al., 2007). This Chapter acknowledges the existence of discourses and debates regarding the definitions of sustainability and sustainable development as these terms seem to be contextual if not broad by definition. In essence, the concept of sustainability has a long history and scientific roots perhaps even dating back to the times when humans first raised concerns over a shortage of natural resources in the interest of the present and future generations (Goodland, 1995; Du Pisani, 2006; Quental, Lorenco & Nunes da Siva, 2011). Though progress in the research arena is unfolding, there are questions raised as the sustainability concept seems to remain unclear if not vague (Komiyama & Takeuchi, 2006; Kajikawa et al., 2007). Not surprisingly, the vagueness in meanings for both sustainable development and sustainability in grasping SS and understanding its mission are all embedded in current debates by those with conflicting positions in the environment-development debate while searching for a common ground (Lele, 1991; Kajikawa et al., 2007).

To the community of sustainability scientists, two essential questions are to be addressed. The first is about defining the mission for SS in considering the importance of research and education by way of contributions toward achieving sustainability. The second is about taking action or how SS can optimally contribute to solving sustainability problems, and what necessary changes in personal attitudes and institutional structures should be in place for such efforts? In answering these questions, it has been asserted that collaboration and partnerships with and across different stakeholder groups be recognized as critical conditions for SS (Blackstock et al., 2007; Whitmer et al., 2010; Spangenberg 2011; Talwar et al 2011). There are challenges that may be difficult to answer i.e., when grasping the mission or goals of SS itself despite a growing body of publications. In juxtaposing positive developments, it is likewise compelling to stress that some camps have called upon the need for improving the academic educational system that would rightfully train students and future sustainability leaders to become agents and innovators for social change (Yarime et al., 2012; Wiek et al., 2012).

A key insight from many of previous studies has been to respond to an ongoing call for an integration of research, education and contributions to society by enhancing the role of higher educational institutions in fostering the goals toward sustainability. As a new science, SS is viewed to address the practical protection for the Earth's key support systems, climate change and other global issues wherein researchers, students and stakeholder groups are visionary, creative and rigorous in developing solutions (PNAS, 2007; Kates, 2011; Wiek et al., 2012; Shahadu, 2016). However, it is noteworthy to reiterate what Wiek et al. (2012) have articulated. Though there is a recognition of SS that it holds some promise to children and future generations, to the marginalized and the disenfranchised yet, some serious thinking must be made on efforts to sufficiently engage with the affected and responsible stakeholder groups and attention to link science and society. Judging from more recent assessments (Wiek et al., 2012), there are remarkable achievements and also failures in SS that we need to strive harder and work smarter to get closer to the promise and prospects of a sustainable world. As a way forward, the community of sustainability scientists need to continue exploring innovative epistemologies and methodologies (from problem-focused to solutions-based research); searching what to do and finding ways how to do it and for investigating ways to create new knowledge and practice with transformational sustainability science agenda (Wiek et al., 2012).

FOCUS OF INTELLECTUAL INQUIRY

Problem solving in the real world is a constant driver in doing research, particularly those that require an integrative and collaborative research approach. The state of the planet's global environmental and resource problems has been reported by large scientific communities with such publications as the Millennium Ecosystem Assessment, the Fourth Assessment Report by the International Panel of Climate Change (IPCC) (2007), The Fourth Global Environmental Outlook (UNEP, 2007), the Human Development Report (UNDP), the State of the World and the World Bank Development Report (Jerneck et al., 2011). Among the issues given are the 'wicked problems' for which the challenges are pervasive and have advanced to levels where human welfare is directly and immediately threatened. These problems are referred to as such because solutions are difficult to identify owing to their complex interdependencies (Ritter & Webster 1972). As exemplified, climate change policies "that promote biofuel production may drive land use changes to an extent where biodiversity, food security and local livelihoods are put at risk" Jerneck et al., 2011: 71).

Hadorn et al., (2010) clearly pointed out that new modes of knowledge production such as transdisciplinary research (TD) aimed to fit knowledge creation to societal needs of solving, mitigating and preventing problems such as violence, disease and environmental pollution. Emphasis has been placed on thinking collectively about complex problems by crossing boundaries both horizontally (across disciplines) and vertically (across experts, policy makers, practitioners and the public) (Klein, 2004; Lele & Norgaard, 2005). As the world continues to pursue research and education, there is a recognition of the shifting modes of knowledge formation, given the urgency of addressing the changes, challenges and their root causes toward achieving a sustainable future (Jerneck et al 2011; Spangenberg 2011; Wiek et al 2011). At some point, sustainability scientists concur there is a need for action to contribute to feasible and effective solution options. The concept of linking knowledge to action for sustainability has been made decades ago (Kates et al, 2001) and has been reiterated since then (Komiyama & Takeuchi, 2006; van Kerkhoff & Lebel, 2006).

Pressing global environmental issues, changes and complex challenges are at the heart of global sustainability research and education goals. While there is rising attention paid by the community of sustainability scientists to investigate the world's sustainability issues, a major concern is to find and frame feasible and effective solutions to global issues such as urbanization pressures, biodiversity loss; protecting the Earth's key support systems and dealing with global climate change, conserve ecosystem services and reduce environmental degradation. Specifically, complex issues facing humanity include an insatiable energy consumption, intensification of urbanization, growing income inequality, threats to food and water security, secure well-being and livelihoods (Jerneck et al., 2011; Steelman et al., 2015). Some asked the question: How do we practice sustainability science so as to reduce inequality, promote health and psychological well-being, and secure livelihoods?

In efforts to find and develop solutions to global issues, interdisciplinary research for instance can be a mode of research engaging teams that integrate information, data techniques, tools, perspectives, concepts and theories from two or more disciplines or bodies of specialized knowledge whose solutions are beyond the scope of a single discipline or area of research practice (Jantsch, 1972; Hadorn et al., 2010). With the need to confront a wide range of global issues in the 21st century, Frodeman (2011) acknowledges the need for knowledge in sustainability and that knowledge production itself must be made sustainable. The process of dealing with global problems using approaches outside of a disciplinary-based mode in problem solving that requires problem identification, structuring and investigation as well as bringing results to fruition (Hadorn et al., 2010).

NEW MODES OF KNOWLEDGE FORMATION/PRODUCTION

In the 1970s, questions were made concerning the orientation of knowledge creation with regard to problem solving and conduct of research and education (Hadorn et al., 2010). Towards the end of the 20th century, the 'knowledge society' have been noted to have developed as debates and discourses continued in framing the relationship between science with technology and issues related to human activities. An important aspect of the rise of SS as a distinct science is the so-called emergence of new modes of knowledge production- in terms of its contributions to research and education as it has brought together various scientists, stakeholders and practitioners.

What has been recognized is that disciplines are currently no longer the 'frames of orientation for the delineation or study of subject matters and formulation of research problems' where traditional single disciplinary approach to systematic inquiry (Weingart, 2010: 12; Turvey, 2015: 42). Largely driven by solving real world problems, the emerging modes of knowledge formation involve academic researchers and societal actors (Hadorn et al., 2010). The new order of knowledge formation involves either transdisciplinary or interdisciplinary modes, not the traditional disciplinary knowledge production (Jantsch, 1972; Funtowiz & Ravetz, 1993; Weingart 2010; Frodeman, 2010). With the growth of interest toward other modes of knowledge formation, research has been characterized to be no longer determined by a single discipline alone, given a diverse or multitude of think tanks, specialized researchers and experts tend to collaborate in the face of scholarly discourses and work together in sustained research. To others the recommended path forward to achieve this kind of science is for researchers to participate in problem-oriented, co-designed, interdisciplinary and transdisciplinary work that can contribute to this vision" (Brewer 1999; National Research Council, 1999; Kates et al. 2001; Kates 2011; Hackman & Clair et al., 2013; Wiek et al 2011; Miller et al., 2014).

In the literature, distinctions have been made in defining transdisciplinarity in relation to interdisciplinarity. In the OECD typology, transdisciplinarity (TD) was "a common system of axioms that transcends the narrow scope of disciplinary worldviews through an overarching synthesis" (Klein, 2005; Weingart, 2010). They challenge the academic status quo in terms of the degree of academic rigour and the proper depth of inquiry. Both are seen to be at its best in the prospects for innovation, in making knowledge more relevant and in gaining more knowledge products that are pertinent to non-academic actors in the accumulation of knowledge.

TD has apparently proliferated as a team-based holistic approach to research that accepts plurality and diversity where a new universality of thought is being developed and informed by a worldview of complexity in science (Klein 2005). In contrast with TD, the view is that the discipline-based work is hierarchical and homogenous compared with the new modes of knowledge production. The new modes seem to foster 'synthetic reconfiguration and recontextualization of knowledge' wherein research being generated continuously is occurring in a broad range of organizations and stakeholders (Gibbons et al., 1994). When lay perspectives and alternative knowledge are recognized, say in a TD mode, what it fosters is a new partnership between the academy and society (Klein, 2010). Historically, a new form of TD was evident in the late 1980s and early 1990s in European contexts of environmental research. Klein (2010) noted that by the turn of the century, case studies were reported in all fields of human interaction within natural systems and technical innovations, that is engaging several disciplines through collaborations between and among academic researchers and the industrial/private sectors. The core premise is that problems in the lifeworld tend to frame research questions and practice, not the disciplines per se (Klein 2010, Weingart, 2010).

Compared to transdisciplinary research, interdisciplinarity (ID) is common throughout basic research in fields such as bioengineering, biophysics, climate change and nanotechnology; involved in experimental research. Reference to ID at times create academic unease because it gives a sense of dissatisfaction to current disciplinary-based mode of knowledge production. Is there truly a level of excessive specialization that there are concerns on how the academy could move forward through new modes of knowledge creation such as an interdisciplinary approach? Frodeman (2011: 107) views otherwise as he commented that interdisciplinarity is a 'boom industry', as the term is mentioned in every university strategic plan. In historical terms, interdisciplinary has attracted scientists from the social as well as natural sciences. Of particular interest is in the physical sciences, of which case studies apply interdisciplinarity in respect of practical challenges and the theoretical issues raised from a science viewpoint. Invariably, terms associated with interdisciplinarity are integrating, interacting, linking, blending and intermeshing within the typology of the interdisciplinary spectrum (Klein, 2010).

Since the 1970s, there has been an exponential growth of publications, a variety of networks and wide discussion of the concept (Klein, 1990). While becoming more important, it involves considerable posturing, boundaries are shifting in ways that make us mindful (Crease, 2010). To put it simply, Schoolman et al., (2011) stressed that if interdisciplinarity is applied, sustainability research 'incorporates concepts, methods and data from a diverse array of academic disciplines." Interdisciplinary approaches in research and education are marked by the 'integration of different disciplinary approaches or methodologies. Interdisciplinary research has been aptly defined by NAS (2004:2) as '… a mode of research by teams or individuals that integrate information, data, techniques, tools, perspectives, concepts and/or theories from two or more disciplines or bodies of specialized knowledge … to solve problems whose solutions are beyond the scope of a single discipline."

Ideas such as interconnectedness of natural and socio-economic systems are key to doing research using this mode in sustainability and sustainable development and for this reason, the principle of interdisciplinarity is deemed critically important (Schoolman et al., 2011). An example is the National Science Foundation (NSF) in the USA which has long recognized the value of interdisciplinary research in fields concerning scientific discovery as research ideas often transcend the scope of a single discipline or program.

As a process, Frodeman (2011) asserts that in this approach, knowledge production crosses and bridges disciplinary boundaries being turned into its own discipline and codified into as an academic product, beyond the irrelevant and the untimely nature of knowledge creation. At times, SS is referred to as an interdisciplinary field concerned with the behaviour and responses of the nature-society system, and the impacts of that system. What should not be ignored is that there are interdisciplinary squabbles due to methodological debates as academics attempt to move beyond the disciplinary epistemology of the 20th century and toward a sustainable epistemology (Frodeman, 2011: 108). Though ID is not exactly the panacea to diverse challenges to research and knowledge production, it has been said that the idea of interdisciplinarity has a place in the 21st century culture of knowledge society (Frodeman, 2011). Though an assertion has been made in previous published works that argue in favour of interdisciplinarity, the future of SS depends on the efforts of researchers and societal actors to share their research results across traditional boundaries but also consider other modes of knowledge production such as transdisciplinarity in this emerging scientific field. SS is an interdisciplinary field concerned with the behaviour and responses of the nature-society system and often, the irreversible response to perturbations of that system. Others point to the interconnectedness of global issues such as climate change and persistent poverty where it has become apparent that interdisciplinarity is important to sustainability research (Schoolman et al., 2011). There is yet another important aspect which, as Frodeman (2011: 111) noted, "… the age of disciplinary knowledge may be ending, but the true shape of interdisciplinarity and the essential characteristics of sustainability, are as yet unknown."

Based on the principle of "inquiring minds want to know", contemporary education is dependent on *inquiry-based learning*. Globalization and technological advances provide a strong foundation for that to happen. Moving away from traditional disciplinary approaches and embracing interdisciplinarity in cutting-edge pedagogical approach that we see around these days. Curriculum development in academic institutions, creation of interdisciplinary research centers, unique research collaborations among unrelated disciplinary experts etc. are becoming very common. Reading a poem on the mesmerizing beauty of flowers in a garden, regenerating a disturbed habitat, using living organisms to bioremediate polluted sites, developing sustainable agricultural practices, saving fisheries, monitoring water quality- Sustainability Science has it all and more. Let us hope the current interdisciplinary efforts will ensure a better future creating environmentally and socially conscious citizens who can problem solve using science-based solutions.

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Chapter 2
A Historic Perspective of Endophytes in Vascular Plants and Their Role in Environmental Sustainability

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ABSTRACT

The term "endophyte" comes from words "endo" meaning within and "phyton" meaning plant. In 1866, De Bary first defined an endophyte as any organism that resides in the tissues of plants but not causing any harm. Thus, endophytes can be a microorganism, usually fungi or bacteria, that colonizes plants parts. The plant tissues/parts where endophytes grow include healthy leaves, petioles, stems, twigs, bark, roots, fruits, flowers, and seeds. They are found virtually in every one of the 300,000 species of vascular plants. Many endophytes co-exist in a single plant host with their populations ranging from one to hundreds of bacterial/fungal species. This chapter outlines a historical perspective of endophytes including ethnobotanical approach to drug discovery. Also, this chapter provides upto date information on the emerging role of endophytes in the sustainability of pasture and economy of agriculture, thereby contributing to the environmental sustainability.

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INTRODUCTION

The term "endophyte" comes from the two words "endo" meaning 'within' and "phyton" meaning 'plant' (Staniek, Woerdenbag, and Kayser, 2008). In 1866, De Bary first defined an endophyte as any organism that inhabits the tissues of plants without causing apparent harm to the host (Nisa et al, 2015; Staniek et. al. 2008). The term now suggests that an endophyte is a microorganism, usually fungal or bacterial, that colonizes plants for part of its lifecycle (Hardoim et al. 2015). Endophytes can inhabit a variety of plant tissues and organs, including healthy leaves, petioles, stems, twigs, bark, roots, fruits, flowers and seeds, and are found in virtually every one of the 300,000 species of vascular plants (Fouda, Hassan, Eid and Ewais, 2015). Many endophyte species can even co-exist in a single host and their populations can range from one to hundreds of bacterial/fungal species, depending on the plant species (Christina, Christapher & Bhore, 2013; Tan & Zou, 2001).

During the 19th century it was widely accepted that healthy plants were sterile and, therefore, free of microorganisms as first postulated by Pasteur (Hardoim et al, 2015). However, in 1887, M. L. V. Galippe found microbes living in healthy vegetable plants and proposed that they were derived from the soil. Galippe was criticized because other scientists had demonstrated that microbes could not live within healthy plants (Compant, Sessitsch & Mathiew, 2012). Endophytes were officially discovered in 1904 in Darnel, Germany (Strobel et al, 2004). However, only recently has it been widely accepted that microorganisms do inhabit healthy plants (Compant et al. 2012).

When Galippe originally documented the colonization of microorganisms in the interior of plants, he proposed that they played a possible beneficial role to the plant (Compant et al. 2012). This, too, was criticized and contrasting studies soon arose (Hardoim et al, 2015). Today, scientists agree that the symbiotic relationship between endophytes and their host varies depending on a variety of factors, including plant and microbe genotype, environmental conditions, and interactions within the plant-microbe biome (Hardoim et al, 2015). The symbiosis ranges from mutualistic to pathogenic, but little is known about the pathogenicity of many endophytes. Some endophytes may lose their virulence under certain conditions; for example, the pathogenic fungus, *Colletotrichum magna*, lost its virulence due to a mutation and became a mutualistic endophyte (Redman, Ranson & Rodriguez, 1999). Different endophyte strains have different degrees of pathogenicity depending on their host; for example, the bacteria, *Klebsiella pneumoniae*, is a human pathogen but it is also a commensal endophyte in other hosts (van Overbeek et al, 2014). Some endophyte-plant symbioses change depending on the conditions; for example, *Pseudomonas* spp., normally found to be beneficial to plants, has been shown to be detrimental to Leatherleaf ferns, *Rumohra adiantiformis*, under specific conditions (Hardoim et al, 2015). Finally, endophyte symbiosis may change depending on the plant host. The fungus, *Verticillium dahliae,* causes a decrease in plant yield to strawberry and olive crops but has a commensal relationship with grapevines and some medicinal plant species. Thus, it is hard to distinguish between pathogenic and nonpathogenic endophytes and, therefore, an "endophyte" must be defined by habitat and not function (Hardoim et al, 2015).

This chapter covers various topics on endophytes such as their classification, diversity, plant-microbe interaction, mechanisms of colonization, transmission, roles of endophytes in plants, enthnobotanical approach to drug discovery and roles of endophytes in environmental sustainability.

CLASSIFICATION

Historical

Originally fungal endophytes were classified into two groups, clavicipitaceous and non-clavicipitaceous, based primarily on taxonomy and life history (Rodriguez, White, Arnold and Redman, 2009). Rodriguez et al. (2009) further divided this classification scheme into 4 classes based on host range, tissue(s) colonized, *in planta* colonization pattern, *in planta* biodiversity, the mechanisms of transmission between hosts, and fitness benefits. Clavicipitacceae family of fungi includes *Balansia* spp., *Epichol*ë spp., and *Claviceps* spp., which only inhabit grasses, rushes and sedges (Hardoim et al, 2015). This group of fungi exhibits both vertical and horizontal transmission (Rodriguez et al, 2009). Most colonize the intercellular spaces of emerging shoots and are transferred vertically through the seeds, but some species, including those from the genra *Neotyphodium* and *Epichlo*ë, can also transmit horizontally when pieces of the leaves fall into the ground (Hardoim et al, 2015). Interestingly, after development *Epichlo*ë species are able to grow on the inflorescence and form collars of mycelium (stromata) on the hosts where *Botanophila* flies visit to lay their eggs (Bultman, Leuchtmann, Sullivan & Dreyer, 2011). These flies carry the gametes of the fungus and, therefore, are involved with cross-fertilization of the fungi (Bultman et al, 2011). Rodriguez et al. (2009) categorizes these clavicipitaceous fungal endophytes as class 1 and non-clavicipitaceous (NC) endophytes into three classes: 2, 3 and 4. Today, Class 2 NC-endophytes is the only confirmed class able to convey habitat-specific stress to the plant host, including temperature, pH, and salinity (Rodriguez et al, 2009). Class 2 NC-endophytes can grow in above and below-ground tissues while class 3 and class 4 can only colonize above-ground tissues and the cortical cell layers of roots, respectively (Rodriguez et al, 2009). Similar to class 1, class 2 can reproduce through both horizontal and vertical transmission and have low endophyte diversity but spread extensively throughout the plant. Class 3 endophytes include members of the phyla Ascomycota and Basidiomycota studied in trees and other plants in diverse ecosystems (Hardoim et al, 2015). Class 3 is only capable of colonizing specific plant tissues but has a wide diversity of endophytes within the host. Class 4 colonizes extensively throughout the plant; however, typical endophyte diversity is unknown because they have not been extensively examined. Class 3 and 4 are only capable of horizontal transmission (Rodriguez et al, 2009).

Recent Work

Although previous work by Rodriguez et al (2009) provides one way to classify endophytes, this scheme does not include other groups of microorganisms, including bacteria, actinomycetes or viruses (Wani, Ashraf, Mohiuddin & Riyaz-Ul-Hassan, 2015). Wani et al (2015) classified endophytes into systemic/true endophytes and nonsystemic/transient endophytes based on taxonomy, diversity, life style, host defense response, ecological functions, evolutionary pattern and mode of transmission. In this scheme, true endophytes exhibit both vertical and horizontal transmission while transient endophytes only exhibit horizontal transmission. True endophytes have co-evolved with their hosts and, therefore, tend to be mutualistic while transient endophytes are only weakly associated with their hosts and range from a mutualistic to parasitic symbiosis (Wani et al, 2015). Due to the mutualism between true endophytes and their hosts, the plant does not require a defense system while hosts of transient endophytes have active defense systems against endophytes.

DIVERSITY

Prokaroytic and Eukaryotic Diversity

A compiled list of all the prokaryotic endophytes as of March 1st 2014 was given by Hardoim et al (2015). 96% of the endophyte diversity is shared between 4 phyla: 54% from Proteobacteria, 20% from Actinobacteria, 16% from Firmicutes and 6% from Bacteridetes. Many members of Archeae were isolated from coffee, cherries, rice and maize roots, as well as from arctic tundra rush *Juncus trifidus* (Hardoim et al, 2015).

26% of the prokaryotes can be categorized as Gammaproteobacteria, including more than 56 different genera and a great number of this group of organisms are phytopathogens. The endophytic Gammaproteobacteria include *Pseudomonas*, *Enterobacter*, *Pantoea*, *Stenotrophomonas*, *Acinetobacter* and *Serratia*. Many members of each of the genera have species that are considered mutualistic while others are pathogenic to their host plant. Alphaproteobacteria were found in 18% of the endophytic sequences (Hardoim et al, 2015). This group of bacteria includes over 57 different genera, including *Rhizobium* and *Bradyrhizobium*, which are capable of fixing nitrogen in legumes. Betaproteobacteria were found in 10% of the sequences and are comprised of over 53 genera, including *Burkholderia, Massilia, Variovorax,* and *Collimonas*. Studies on the genus *Burkholderia* strains have shown they are capable of colonizing a wide range of hosts and environments, therefore, suggesting this genus is capable of great metabolic and physiological adaptability (Hardoim et al, 2015).

Gram-positive endophytes, including the class Actinobacteria, comprised 20% of the sequences with over 107 genera. This group comprises genera including *Steptomyces, Microbacterium, Mycobacterium, Arthrobacteria and Curtobacterium*. The class Bacilli represents 15% of the sequences with more than 25 genera identified (Hardoim et al, 2015).

The same study compiled a list of all the eukaryotic endophytes by comparing the internal transcribed spacer (ITS) sequences of the endophytes to the NCBI nucleotide database to identify the endophytes. This data revealed that most of the endophytes belong to one of four phyla: Glomeromycota (40%), Ascomycota (31%), Basidiomycota (20%) and unidentified phyla (8%) (Hardoim et al, 2015). The phylum Glomeromycota includes ecologically and economically important endophytes, including arbuscular mycorrhizal fungi (AMF) (Hardoim et al, 2015). The class Glomeromycetes represents nearly all (39%) of the endophytes in this phylum. In the phylum Ascomycota most of the endophytes were from the class Dothideomycetes (15%); these include many pathogenic fungi. In the phylum Basidiomycota most of the endophytes were from the class Agaricomycetes (18%), including ectomycorrhizal (EMC) fungi (Hardoim et al, 2015).

Temperate vs. Tropical Diversity

In general, there is little knowledge about endophyte composition over biogeographic regions (Arnold, 2007). Differences in culture media, tissue piece size and the treatment of tissue, i.e. removal of epiphytes, make it difficult to draw strong conclusions between areas when examining different studies (Arnold, 2007). Arnold and Lutzoni (2007) compared the molecular sequence of 1403 endophyte strains in the Canadian Arctic and Tropical sites in Central Panama. Results indicated that there was an increase in the number of endophytes from the Arctic to the tropics from <1% to >99% of the tissues containing endophytes (Arnold & Lutzoni, 2007). There was also a change in species composition from the Arctic to the tropics (Arnold, 2007). Angiosperms in the Arctic had at least six classes of Ascomycota but had lower species diversity (Arnold & Lutzoni, 2007). The plants in tropical sites had rich species diversity but had endophytes from only three classes. Finally, endophytes in the Arctic had a narrow range of hosts compared to the tropics. In general, studies show that tropical trees have the highest species diversity for fungal isolates (Arnold & Lutzoni, 2007; Hawksworth, 2001). Recently, it was proposed that half of the newly discovered fungi came from tropical regions (Hawksworth, 2001). Generally, fungal diversity is predicted to be the greatest in humid tropical islands, tropical mountaintops and large tropical forests (Hawksworth, 2001).

PLANT-MICROBE INTERACTIONS

Phenotypic plasticity has allowed plants to evolve with changing abiotic environments, with biotic microbes living in the surrounding soil and has also allowed them to co-evolve with the endophytes living inside them (Goh, Veliz Vallejos, Nicotra & Mathesius, 2013). This co-evolution impacts the growth, development, fitness and diversity of plants (Hardoim et al, 2015).

Two major interactions have been extensively studied: arbuscular mycorrhizal (AM) symbiosis and root nodule (RN) symbiosis (Kawaguchi and Minamisawa, 2010). AM fungi in the division Glomeromycota can be found living inside nearly 80% of plant families. The RN symbiosis is the interaction between plants and nitrogen-fixing bacteria (Kawaguchi and Minamisawa, 2010). The first nitrogen-fixing bacteria were isolated by Martinus Beijerinck from the root nodule of legumes in 1888 (Hardoim et al, 2015). AM symbiosis is the interaction between plants and endomycorrhizal fungi that penetrate the cortical root cells of plants (Kawaguchi & Minamisawa, 2010). Mycorrhizal fungi were discovered by Albert Bernhard Frank who reported on the mutualistic relationship between tree roots and underground fungi (Hardoim et al, 2015).

ENDOPHYTE COLONIZATION

Plants have evolved barriers to prevent colonization by endophytes that vary between species, depending on the colonization strategies of the endophytes (Saunders, Glenn, & Kohn, 2010). Some endophytes produce enzymes that degrade the waxes and cell walls of the plants which allow for penetration of the host's tissues while other endophytes enter through open wounds, stomata or hydathodes (Saunders et al. 2010). As plants evolve, changes in leaf chemistry and resistance to herbivory determine which endophytes are able to colonize the plant (Saunders et al. 2010). Many bacterial endophytes living in the rhizosphere environment are attracted to the plant because of exudates and rhizodeposits from the roots. Studies suggest that the endophytes originally colonize the root hairs (Hardoim et al, 2015). The stem and leaf surfaces also produce exudates; however, UV light that shines on these surfaces reduces the endophyte's ability to survive because of lack of nutrients and risk of desiccation. The specific area of colonization depends on the endophytic strain (Hardoim et al, 2015; Zabalgogeazcoa, 2008). Some endophytes can only colonize through the rhizoplane to the cortical cell layer because colonization beyond that is prevented by the plant's endodermis. Others are able to penetrate the endodermis entering the xylem, which is used as a transport route to other internal plant compartments, while others colonize the intercellular spaces near the roots (Hardoim et al, 2015). Endophytes have been isolated from flowers (epidermis and ovary), fruits (pulp) and seeds (tegument) of Angiosperms, including grapevine flowers, and the pollen of Gymnosperms.

ENDOPHYTE TRANSMISSION

Endophytes use two modes of dispersal: vertical or horizontal transmission (Zabalgogeazcoa, 2008). Horizontal transmission occurs when an endophyte moves between individuals other than parents while vertical transmission happened when an endophyte moves from prents to offspring. Although endophytes are transmitted vertically by colonizing the seeds, many also live in the host's surrounding environment that can be transmitted horizontally within a community/population (Hardoim et al, 2015). Nearly all of the plants infected by endophytes produced seeds that contain fungal hyphae near the embryo that then develop into asymptomatic infected plants. Evidence suggests that horizontal transmission is the predominant mechanism for dispersal because the seeds of many saplings are often free from endophytes and there is an increase in the number of endophytes as the plants age (Zabalgogeazcoa, 2008). Scientists believe that the leaf litter of infected plants may provide a source of endophytic inoculum to the surrounding soil. Some plants are also able to transmit endophytes horizontally in other ways; for example, *Epichlo*ë endophytes may infect other grasses through a microscopic layer of hyphae and conidia on the leaf surface (Zabalgogeazcoa, 2008). Additionally, phytophagous insects may be able to transmit endophytes to new hosts because some fungal spores are resistant to digestion and remain intact in the insects' fecal matter.

ROLES OF ENDOPHYTES IN PLANTS

Plant Growth

Endophytes increase the growth of plants and this should mean fewer nutrients are available to the microbe. However, the high densities of endophytes found in many plants indicate that this must be neutral or beneficial to both the host and the endophytes (Hardoim et al, 2015).

Providing Biofertilizers

Some bacteria increase the mineral nutrients available to plants, including nitrogen, phosphorous and iron, which are essential nutrients in the growth of terrestrial plants (Gaiero et al, 2013; Weyens, van der Lelie, Taghavi, Newman & Vangronsveld, 2009). The "biofertilizers" fix and solubilize mineral nutrients otherwise unavailable to plants. Increasing the nutrient availability for plants can decrease the use of fertilizers in agriculture (Weyens et al, 2009).

Nitrogen

Some bacteria, called diazotrophs, are able to fix atmospheric nitrogen into ammonia or nitrate and other compounds, making them accessible to plants (Weyens et al, 2009). Extensive research has gone into the endophytic transfer of nitrogen to the host for carbohydrates, especially in legumes (Mei & Flinn, 2010). Grains infected with the diazotroph, *Azorhizobium caulinodans*, showed increased yield and biomass by 34% and 39% respectively (Weyens et al, 2009). Although nitrogen fixation is often limited in non-leguminous plant-rhizome relationships, *Gluconacetobacter diazotrophicus* inside sugarcane, a non-legume plant, is able to fix nitrogen and other *G. diazotrophicus* strains in pine needles were found to potentially fix nitrogen (Hardoim et al, 2015). Many endophytes are capable of fixing nitrogen in poplar (*Populus* spp.) and willow (*Salix* spp.) trees, possibly allowing these trees to live in soils low in nitrogen (Weyens et al, 2009).

Phosphorous

Yazdani and Bahmanyar (2009) showed that the use of plant growth promoting rhizobacteria (PGPR) in phosphorous fertilizers allowed for a 50% decrease in the quantity of fertilizers needed to be applied to corn (*Zea mays*) without causing losses in crop yields (Gaiero et al, 2013). The bacterial endophytes isolated from soybeans found that 52% were capable of solubilizing mineral phosphate. Increasing the availability of phosphorous may lead to increased growth; for example; mustard greens (*Brassica juncea*) infected with *Bacillus subtilis* SJ-101 showed elongation and enlargement of both the shoot and roots (Weyens et al, 2009).

Iron

Many microorganisms produce siderophores, which acquire iron from the soil (Hardoim et al, 2015; Weyens et al, 2009). Siderophores bind to Fe^{+3} so it can be reduced to Fe^{+2} which can be utilized by plants. Microorganisms are able to regulate siderophore production and decrease iron competition for plants in the rhizosphere (Weyens et al, 2009). Siderophores in *E. festucae*-infected ryegrasses may regulate iron homeostatsis (Hardoim et al, 2015).

Growth Hormones

Phytohormone production, including auxins, gibberellins, cytokines and ethylene, by endophytes promotes the growth of plants (Hardoim et al, 2015; Mei & Flinn, 2010). The production of auxins and gibberellins is usually found in root-associated endophytes (Hardoim et al, 2015). Auxin indole-3-acetic acid (IAA), produced by many endophytes, has been shown to increase root growth and length as well as the proliferation and elongation of root hairs (Weyens et al, 2009). For example, roots of *Brassica juncea* infected with *Variovorax paradoxus* 5C-2 lengthened by up to 41%. Some IAA-producing bacteria include *Azospirillum brasilense*, *Aeromonas veronii, Agrobacterium* spp., *Alcaligenes pichaudii, Bradyrhizobium* spp., *Comamonas acidovorans*, *Enterobacter* spp. and *Rhizobium leguminosarum* (Weyens et al, 2009).

Gibberellins have shown to increase growth of the stem but also have a minor role in root development (Mei & Flinn, 2010). *Bacillus pumilus* and *Bacillus licheniformis* species produce gibberellins, which increase plant growth and yield (Weyens et al, 2009).

Cytokines produced by endophytes are associated with promoting the opening of stomata, shoot growth and decreased root growth. Decreases in cytokines occur when soils are dry: the stomata close and growth is directed to the roots allowing for increased drought tolerance (Weyens et al, 2009).

Ethylene concentrations increase during periods of stress. It plays a role in the inhibition of root elongation, lateral root growth and the formation of root hairs (Weyens et al, 2009). Some bacteria produce increased levels of auxins to balance the ethylene levels in the plant. While other bacteria produce 1-aminocyclopropane-1-carboxuylate (ACC) deaminase that cause the plants to decrease the levels of ethylene, promoting growth. For example, *Burkholderia phytofirmans* strain PsJN produces large amounts of ACC in potatoes, tomatoes and grapevines (Mei & Flinn, 2010).

Protection Against Abiotic Stress

Abiotic stress such as droughts, high salinity, heat or cold, and oxidative stress commonly decrease growth and productivity of plants (Singh, Gill & Tuteja, 2011). Research indicates that the type of abiotic stress that the microbe relieves is habitat specific. For example, geothermal endophytes only decrease heat stress while coastal endophytes only decreases salt stress (Mei & Flinn, 2010).

Drought

Drought is a major limiting factor of plant growth globally (Mei and Flinn, 2010). The endophytic fungi, *Neotyphodium* spp., are able to improve the drought tolerance of grasses by osmo- and stomata regulation (Hardoim et al, 2015). Compared to uninfected plants, *Neotyphodium coenophialum* infected fescues show increased drought tolerance: more tiller, higher biomass, seed mass and seed number and higher germination rates (Mei & Flinn, 2010). The *Neotyphodium-Lolium perenne* symbiosis allows for increased root/shoot ratio beneficial in droughts (Mei & Flinn, 2010). Increased drought tolerance in maize and wheat plants was shown in those plants infected by *Burkholderia phytofirmans* strain PsJN (Hardoim et al, 2015). Endophytes that produce loline alkaloids in response to drought, that are nontoxic to plants and highly water soluble, also have a positive effect on drought tolerance (Singh et al. 2011).

Salinity

Globally, 20% of agricultural lands and 50% of croplands have increased salinity (Mei & Flinn, 2010). The fungal endophyte *Piriformospora indica* increased salt tolerance in barley and drought tolerance in Chinese cabbage plants (Hardoim et al, 2015). Both were due to the production of antioxidant enzymes and increases in the ascorbic acid concentrations in the host (Hardoim et al, 2015; Mei & Flinn, 2010). The native dunegrass, *Leymus mollis*, is only able to live in coastal habitats because of the habitat-adapted endophyte, *Fusarium culmorum,* which confers salt tolerance to its host (Singh et al. 2011). Some bacteria produce exopolysaccharides, which can bind to Na^+ making it unavailable to plants in soils of high salinity (Grover, Ali, Sandhya, Rasul & Venkateswarlu, 2011). *Glomus* spp. are known to increase the phosphate and decrease the salt concentrations in stems of plants such as maize, mung beans and clover (Grover et al, 2011).

Extreme Temperatures

Severe hot and cold temperatures have the ability to destroy photosynthetic apparatus and cell membranes of plants, which can be alleviated by endophytes (Mei & Flinn, 2010). For example, the bacterial endophyte *Burkholderia phyrofirmans* strain PsJN increased the cold tolerance of grapevine plantlets allowing for increased growth and ability to maintain physiological activity for the plant (Hardoim et al, 2015). *Dichanthelium lanuginosum*, a species of grass, was inoculated with *Curvularia protuberata*, a fungal endophyte, and was able to tolerate high temperatures. The plant-fungal symbiosis was able to tolerate temperatures of 65°C; however; seperately they were only able to tolerate temperatures of 40°C (Hardoim et al, 2015).

Protection Against Biotic Stress

Induced Systemic Resistance (ISR)

Endophytes, such as bacteria and fungi, have a shorter generation time than plants and, therefore, can evolve faster than their host (Hardoim et al, 2015). Because of this, there are more endophyte forms resistant against pathogens and herbivores than their hosts (Alvin et al, 2014; Hardoim et al, 2015). The activation of the plant's defense system through induced systemic resistance (ISR) allows the plant to have a higher tolerance to the pathogen or pest (Hardoim et al, 2015; Ryan et al, 2008). Fungal endophytes use ISR less frequently compared to bacterial endophytes. The endophyte in potato plant shoots, *Methylobacterium* sp. strain IMBG290, is capable of inducing resistance against *Pectobacterium atrosepticum*, a plant pathogen (Hardoim et al, 2015). Kloepper and Ryu (2006) found the endophytes *Bacillus pumilus* INR7 and *Serratia marcescens* 90-166, provoked ISR on 5 and 6 host plant species respectively (Yi, Yang and Ryu, 2013). These bacteria were able to activate the host's immune system and promote growth concurrently (Yi et al. 2013).

Pest Control

Perennial ryegrasses (*L. perenne*) hosting the fungal endophyte, *Neotyphodium lolii*, have fewer aphids feeding on them and, the aphids that did, had a reduced life span (Mei & Flinn, 2010). In addition, the grass Fowl mannagrass (*Glyceria striata*), was infested by fewer fall armyworm caterpillars when colonized by *Epichloë glyceria*. Tomato plants infected with the endophyte *Fusarium oxysporum* strain 162 showed fewer rates of infection by the nematode, *Meloidogyne incognita* (Mei and Flinn, 2010). The production of alkaloids by these endophytes is a major source of toxicity to both mammals and insects (Clay, 1988). Some alkaloids include ergot alkaloids, aminopyrrolizidine alkaloids, pyrrolopyrazine alkaloids, indole diterpenoid alkaloids, and 11,12-epoxy-janthitrems (Mei & Flinn, 2010). The alkaloid concentration within the plant varies depending on plant part, host species, age and growing season etc. The loline alkaloid production in the seeds of tall fescue may provide the plant with protection from predation (Clay, 1988).

Phytopathogens

Endophytes are able to decrease the occurance and severity of disease in many plants, including wheat, bananas, sugar canes, Chinese cabbage and beans (Mei & Flinn, 2010). By living in the same ecological niche as the pathogen, endophytes compete for resources reducing the occurrence of pathogens. However, endophytes can also produce compounds, which are toxic to the pathogen (Mei & Flinn, 2010). Endophytes, which produced siderophores, such as pyochelin and salicylic acid, compete for trace metals and, thus, help manage many pathogens indirectly (Gaiero et al, 2013). *Burkholderia phytofirmans* strain PsJN inhibits the growth of the plant pathogen, *Botrytis cinerea,* the cause of gray mold disease in many plants, by disrupting its cellular membranes causing cell apoptosis (Mei & Flinn, 2010). Western white pines (*Pinus monticola*) with fungal endophytes showed enhanced survival when infected by the pathogen, *Cronartium ribicola*, which causes white pine blister rust. Sometimes endophytes are not capable to inhibiting pathogens themselves but need the plant-microbe interaction, such as, the Dvd-E6 endophyte which was not able to inhibit Vd1 (a virulent *Verticillium*) *in vitro* but was able to protect tomato plants (Mei & Flinn, 2010).

Phytoremediation

Endophytic bacteria may provide a cheaper solution to clean-up the environment from toxic chemicals than traditional methods (McGuinness & Dowling, 2009). Enzymes produced by endophytes can degrade the toxic chemicals thereby contributing to phytoremediation of soil and water (McGuinness & Dowling, 2009). A variety of endophytes was proven to be successful agents in bioremediation, including bacteria from the genera *Herbaspirillum, Pseudomonas, Burkholderia* and *Methylobacterium*. In another study, Pea (*Pisum sativum*) plants with a bacterial endophyte were able to degrade a 2,4-D herbicide naturally from the soil and left no 2,4-D contamination in the above ground plant parts (Mei & Flinn, 2010). Yellow lupine infected with engineered endophyte, *Burkholderia cepacia* L.S. 2.4., degraded toluene, reducing phytotoxicity (Mei & Flinn, 2010; Weyens et al, 2009).

ETHNOBOTANICAL APPROACH TO DRUG DISCOVERY

Ethnobotanical Knowledge

Natural products are those derived from metabolites or by-products of microorganisms, plants and/or animals. For thousands of years, these natural products have been exploited by humans, including the Mayans almost 3,000 years ago (Strobel & Daisy, 2003). Many groups use plant compounds for medicine, including 2,600 species of vascular plant used by North American Native peoples (Frey & Meyers, 2010). Today, 80% of the world's population still uses herbal medicines (Alvin, Miller & Neilan, 2014). The chemical for the drug aspirin (salicylic acid) was originally isolated from plants from the *Salix* and *Populus* genera (Strobel & Daisy, 2003). Almost all of the traditional medicinal plants have a closely linked phylogenic relationship (Frey & Meyers, 2010). Unfortunately, ancient medicines were sacred to many prehistoric groups and, therefore, their traditional knowledge was lost (Alvin et al. 2014). Ethnobotanic medicinal plants provide important knowledge for research into new medicinal properties (Alvin et al. 2014).

Importance of Natural Product Discovery

Today, 49% of new chemical compounds permissible by the U.S. Food and Drug Administration are natural products or their derivatives. From 1983 to 1994, over 60% of existing cancer drugs and cancer drugs being developed have natural origins (Strobel & Daisy, 2003).

Natural products from plants can be developed to treat life-threatening diseases, drug-resistant microbes, and diseases with no existing, effective treatment (Alvin et al. 2014). Natural products may identify a molecule, which can then be manipulated through combinatorial and synthetic chemistry, to enhance activity (Strobel & Daisy, 2003).

Endophytes as a Source of Natural Products

The discovery of penicillin isolated from a fungus and the production of penicillin in mass quantities during World War II has led to research into microorganisms that produce metabolites with antimicrobial activity against human pathogens (Alvin et al. 2014; Strobel & Daisy, 2003). The endophyte and plant host often produce the same or similar secondary metabolites, including the anticancer drug camptothecin and anticancer compound podophyllotoxin. However, large quantities of plants need to produce enough natural products for commercial use. One way to alleviate these issues is to study the microorganisms living inside the plant tissues that produce the same or similar compounds in order to meet pharmaceutical requirements (Alvin et al. 2014). Large-scale production and manipulation of biologically active compounds is easier in these microorganisms when compared to plant hosts and, therefore, microorganisms provide opportunity to return to natural product discovery. Because endophytes produce the same or similar secondary metabolites as their host, there are many hypothesized mechanisms for the simultaneous production of these compounds. For example, gibberellin is synthesised independently in the endophyte and plant (Alvin et al. 2014). Studies also suggest that the interaction between the endophyte and host must occur for the production of bioactive molecules in many cases (Alvin et al. 2014). It has shown that the endophyte-host symbiosis produces a greater amount and diversity of biological molecules when compared to epiphytes and soil microbes and the relationship is likely to reduce the toxicity of chemicals in the host cells and, therefore, is less likely to kill eukaryotic host systems. Therefore, endophytes are important sources of natural products used in new drug discovery (Alvin et al. 2014).

Endophytes Bioactive Compounds

Fungal and bacterial endophytes produce secondary metabolities that are antifungals, antibacterials, antidiabetics, antioxidants and/or immunosuppressants (Christina et al. 2013). In fact, most endophytic bacteria produce antibiotics, including ecomycins, pseudomycins, munumbicins, and kakadumycins (Christina et al. 2013).

Anticancer Compounds

Cancer is the unregulated growth of abnormal cells (Pimentel, Molina, Dionisio, Junior & Pastore, 2011). 50 different fungal endophyte species are known to produce over 100 anticancer compounds (Bano et al, 2016). The diterpenoid Paclitazel (Taxol) is an anticancer drug originally isolated from a Yew tree (*Taxus brevifolia*) (Alvin et al. 2014; Bano et al, 2016). This compound became the world's first drug used to treat cancer, including breast, lung and refractory ovarian cancer, but was not readily available due to the high cost (Pimentel et al, 2011). In 1993 an endophytic fungus, *Taxomyces andreanae,* that produced paclitaxel was discovered (Strobel & Daisy, 2003; Zhao et al, 2010). Since this discovery, at least 19 endophyte genera have been found to produce Taxol or its derivatives, including *Alternaria, Aspergillus, Botryodiplodia, Botrytis, Cladosporium, Ectostroma, Fusarium, Metarhizium, Monochaetia, Mucor, Ozonium, Papulaspora, Periconia, Pestalotia, Pestalotiopsis, Phyllosticta, Pithomyces, Taxomyces, Tubercularia* (Zhao et al, 2010).

Podophyllotoxin (PDT) is an aryltetralin lignan originally isolated from traditional medicinal Podophyllum plants in the Himalayas and in North America (Mousa and Raizada, 2013). PDT was isolated from the endophyte, *Fusarium oxysporum*, infecting the Himalayan medicinal plant *Juniperus recurva* (Mousa and Raizada, 2013). Today, derivatives of PDT are used in chemotherapy for various cancers (Selim, El-Beih, Abdul-Rahman & El-Diwany, 2012). PDT is a precursor to anticancer drugs such as etoposide, tenioside and etopophose phosphate (Bano et al, 2016). Most of the natural PDT comes from *Sinopodophyllum* plants, which are quickly being depleted. In addition to *Sinopodophyllum* spp. endophytic fungi that produce this compound have been isolated from *Sabina* vulgaris, *Salbina recurva, Dysosma* veitchii, and *Diphylleia sinensis* (Zhao et al, 2010). This compound inhibits the growth of cancer cells by preventing cell division (Mousa & Raizada, 2013).

Alkaloids are important anti-cancer compounds, including three cytochalasins isolated from the endophyte *Rhinocladiella* sp. living inside *Tripterygium wilfordii* (Pimentel et al, 2011; Selim et al, 2012). The alkaloid camptothecin (CPT) was first originally isolated in China from wood in the deciduous tree, *Camptotheca acuminata* (Pimentel et al, 2011; Zhao et al, 2010). The major supply of CPT comes the trees *Camptotheca acuminata* and *Nothapodytes nimmoniana*; however, supplies must increase with demand. CPT has also been isolated from the fungal endophyte *Entrophospora infrequens* inhabiting *Nothapodytes foetida* and is an important antineoplastic agent. CPT inhibits DNA replication and transcription (Zhao et al, 2010). CPT and its analogue, 10-hydroxycamptothecin, are precursors to the semi-synthetic drugs, Hycamtin (topotecan) and Camptosar (irinotecan), which have been used to treat ovarian, lung and refractory ovarian cancers (Selim et al, 2012; Zhao et al, 2010).

Two anticancer compounds from the class ergochrome have been isolated from endophytes. The first anticancer agent ergoflavin has been isolated from a fungal endophyte isolated from the plant *Mimusops elengi* (Pimentel et al, 2011; Selim et al, 2012). The second, secalonic acid D was isolated from a fungal endophyte that causes leukemia cell apoptosis and high cytotoxicity on HL60 and K562 cells (Pimentel et al, 2011).

Vinblastine and vincristine are terpenoid indole alkaloids known to be anticancer agents. The first endophyte known to produce vinblastine was *Alternaria* sp. isolated from *Catharanthus roseus* (Zhao et al, 2010). In another study the endophyte, *Fusarium oxysporum*, also isolated from *C. roseus,* was able to produce vincristine. Vincristine is able to disrupt cell division, intracellular transport and decrease blood flow to the tumor (Zhao et al, 2010).

Immunosuppressant Compounds

Endophytes also produce compounds that influence immune systems (Wani et al. 2016). Fungal endophyte extracts from *Petriella* sp. and *Ulocladium* sp. isolated from *Pinus roxbergii* and *Cochliobolus spicifer* isolated from *Cedrus doedara* and *Sordaria superba* and *Fusarium redolens* from *Artemisia* sp. have shown to have immunosuppressant activity (Wani et al, 2016).

Subglutinols A and B are immunosuppressant compounds produced by the endophyte, *Fusarium subglutinans*, isolated from the vine, *Tripterygium wilfordii* (Lee, Lobkovsky, Pliam, Strobel & Clardy, 1995). This compound may be used in the treatment of autoimmune diseases like rheumatoid arthritis and insulin dependent diabetes (Wani et al, 2016). In addition, a common immunosuppressant, cyclosporine, has also been isolated from a fungal endophyte, *Pestalotiopsis microspora* (Christina et al. 2013).

Antioxidant Compounds

Antioxidant compounds inhibit the damage caused by reactive oxygen species (ROSs) and oxygen-derived free radicals, including DNA damage, carcinogenesis and cellular degeneration (Pimentel et al, 2011). Natural antioxidants can be found in plants, vegetables and fruits but endophytes are another source of natural antioxidants (Pimentel et al, 2011). Methanol extracts containing phenolics and flavonoids from the endophyte, *Xylaria* sp., isolated from the medicinal plant, *Ginkgo biloba,* been shown to have strong antioxidant activity (Pimentel et al, 2011; Selim et al, 2012). The compounds pestacin and isopestacin also have antioxidant activity. Both compounds were produced by the endophyte, *Pestalotiopsis microspora*, living inside the tree *Terminalia morobensis* in Papua New Guinea (Pimentel et al, 2011; Selim et al, 2012).

The fungal endophytes, *Cephalosporium* sp. and *Microsphaeropsis* sp., living inside the plants, *Trachelospermum jasminoides* and *Pilgerodendron uviferum*, respectively were found to produce a phenolic compound called graphislactone A with antioxidant effects (Selim et al, 2012). The antioxidants corynesidones A and B and cornether A are produced by the endophyte, *Corynespora cassiicola*. Corynesidone A also has anti-aromatase activities similar to the drug aminoglutethimide and, therefore, may be useful in chemoprevention for breast cancer (Selim et al, 2012).

Antimicrobial Compounds

Many types of antimicrobial compounds have been isolated from endophytes, including alkaloids, peptides, steroids, terpenoids, phenols, and aliphatic compounds (Yu et al, 2010).

Alkaloids are commonly produced by endophytic fungi (Strobel & Daisy, 2003). Cytochalasins are produced by endophytes in the genera *Xylaria, Phoma, Hypoxylon* and *Chalara* (Strobel & Dsaiy, 2003). Peramine is a pyrrolopyrine alkaloid produced by the fungus, *Acremonium lolii*, inhabiting infected perennial ryegrass (*Lolium perenne* L.). The endophyte, *Neotyphodium* sp., also produced different levels of peramine depending on the plant genotype. Studies have shown that this compound acts as an anti-feedant, without negatively impacting mammals (Mousa & Raizada, 2013). The antibiotics, pyrrocidines A and B, have been isolated from the endophyte, *Acremonium zeae*, in maize and possess antifungal activity against *Aspergillus flavus* and *Fusarium verticillioides* (Yu et al, 2010).

Peptides are also important antimicrobial compounds produced by endophytes (Yu et al, 2010). The antimicrobial peptide, leucinostatin A, has been isolated from the endophyte, *Acremonium* sp., infecting European yews (*Taxus baccata*) (Mousa and Raizada, 2013). The peptide, cryptocandin, isolated from the endophyte, *Cryptosporiopsis quercina,* and inhabiting the host, *Tripterigium wiflordii*, has shown antibacterial activity against *Candida albicans* (Strobel et al, 2004; Yu et al, 2010).

Steroids produced by endophytes exhibit moderate antibacterial properties (Yu et al, 2010). Ergosterol and 5α-8α-epidoxyergosterol have been isolated from the fungal endophyte, *Nodulisporium* sp., living inside a *Juniperus cedre* tree (Bano et al, 2016; Yu et al, 2010). Penicisteroid A is a steroid produced by the endophyte, *Penicillium chrysogenum*, isolated from red algae in the genus, *Laurencia*. This compound has antifungal activity against, *Aspergillus niger* (plant black mold) and moderate activity against *Alternaria brassicae* (*Brassica* spp. plant pathogen) (Moursa & Raizada, 2013).

Terpenoids, including sesquiterpenes, diterpenoids and triterpenoids, have all been isolated from endophytes (de Souza, Vieira, Rodrigues-Filho & Braz-Filho, 2011). Over 127 terpenoids have been isolated from endophytic fungi and many have antimicrobial, anticancer and antiprotozoa activity (de Souza et al, 2011). For example, phomenone is a sesquiterpene isolated from the endophyte, *Xylaria* sp., inside the tree, *Piper aduncum* (Mousa & Raizada, 2013). This compound has antifungal activity against *Cladosporium cladosporioides* (wheat pathogen) and *C. sphaerospermum* (mold) (Mousa & Raizada, 2013).

Phenols and phenolic acids with antimicrobial activity have also been isolated from endophytes. For example, colletotric acid has been isolated from *Colletotrichum gloeosporioides* living inside the stems of *Artemisia mongolica* (Mousa & Raizada, 2013). This compound has antibacterial properties against *Bacillus subtilis, Staphylococcus aureus,* and *Sarcina lutea* as well as antifungal properties against *Helminthosporium sativum* (Mousa & Raizada, 2013). The phenolic acids, p-hydroxybenzoic acid, p-hydroxyphenylacetic acid, tyrosol and p-coumaric acids, have antifungal activity and were purified from the endophyte, *Epichloë typhina* (Mousa and Raizada, 2013). This endophyte can be commensal or pathogenic to the host *Phleum pratense* (European timothy-grass) (Mousa & Raizada, 2013).

Aliphatic compounds produced by endophytes are often antimicrobial (Yu et al, 2010). Brefeldin A is known to be produced by *Penicillium* sp., an endophyte isolated from the roots of *Panax ginseng* (Yu et al, 2010). This aliphatic compound was also isolated from the antifungal endophyte, *Cladosporium* sp., isolated from *Quercus variabilis* (Pimentel et al, 2011). This particular compound has shown to have antimicrobial activity, such as antibacterial, antiviral, anti-nematode and antifungal activities, including antifungal properties against *Aspergillus niger*, *Candida albicans* and *Trichophyton rubrum* (Mousa & Raizada, 2013). In the host conifers *Taxus mairei* and *Torreya grandis* the fungal endophytes, *Paecilomyces* sp. and *Aspergillus clavatus* respectively, were also both found to produce brefeldin A (Mousa & Raizada, 2013). Gamahonolide A and B produced by the endophyte, *Epichloë typhina*, inhabiting the grass *Phleum pratense*, has been known to have antifungal activity against *Cladosporium herbarum*. This fungus is a common plant pathogen and may cause allergies in humans (Mousa & Raizada, 2013).

Antiviral Compounds

Endophytes are also able to produce compounds that inhibit the activity of a variety of viruses, including human immunodeficiency virus (HIV), influenza virus H1N1, and the herpes virus (Selim et al, 2012). For example, an endophyte isolated from the leaves of *Quercus coccifera* was able to synthesize hinnuliquinone, which inhibits the human immunodeficiency virus type 1 (HIV-1) protease. Emerimidine A and B from the endophyte, *Emericella* sp., moderately inhibited the influenza virus H1N1. Mellisol and 1,8-dihydroxynaphthol 1-O-a-glucopyranoside were synthesized from the endophyte, *Xylaria mellisii*, which inhibits the herpes simplex virus type 1 (Selim et al, 2012).

ROLES OF ENDOPHYTES IN ENVIRONMENTAL SUSTAINABILITY

Increase in human population has had local and global environmental consequences. These anthropogenic environmental changes have led to concerns over the sustainable use of renewable resources and non-renewable resource depletion, as well as the need to assess ways to reduced environmental degradation, including land use and pollution. Endophytes may be beneficial in some environmental sustainable development such as in developing sustainable agriculture to meet the needs of future generations and may also act as potential biofuels (Kauppinen, Saikkonen, Helander, Pirttila & Wali, 2016).

Sustainable Agriculture

Sustainable agricultural practices are necessary in order to combat the major challenges presented by the global food crisis (Kauppinen et al, 2016). Between 2010-2012, it was estimated that 12.5% of the global population was malnourished; this is expected to increase as the population is estimated to reach 9.7 billion by 2050 (Le Cocq, Burr, Hirsch & Mauchline, 2017). Abiotic and biotic stresses on agriculture create limitations on plant yields. Pathogens, flooding, drought, soil infertility and other factors all contribute to these stresses. In addition, climate changes intensify the frequency and severity of these issues (Le Cocq et al, 2017). Currently, agriculture relies on the use of chemical pesticides and fertilizers (Kauppinen et al, 2016; O'Callaghan, 2016). However, these are no longer sustainable and changes are being made to reduce the human and animal health impacts of these chemical compounds (Kauppinen et al, 2016; O'Callaghan, 2016). Stricter legislation regarding the use of pesticides around the world is being implemented and increased development and registration costs of synthetics limit the control options for growers (O'Callaghan, 2016). Naturally occurring alternatives such as biopesticides and plant growth-promoting microorganisms may allow for sustainable agriculture without the negative effects to human health and the environment (Kauppinen et al, 2016; O'Callaghan, 2016).

Pasture Sustainability

Pastures of grasses are used for grazing animals and/or hay production, which contributes to significant land use coverage globally (Young, Hume & McCulley, 2013). These areas provide both economic and ecosystem benefits as they promote carbon sequestering, preserve biodiversity reduce soil degradation, and support water quality and quantity (Young et al. 2013). In addition, grassland pastures are important in agriculture for both sustainable meat and dairy production. Sustainable pastures require few inputs, maintain continual nutrient cycling, and produce quality forage for either animals or hay production that is economically sound and resistant to climate change and pests (Young et al. 2013). Grasslands are significantly affected by extreme weather conditions, causing impacts such as water scarcity, overgrazing and erosion (Kauppinen et al, 2016). Tall fescue and perennial ryegrasses are some of the most used foraging grasses in pastures globally. Many species in the genera *Epichloë and Neotyphodium* have symbiotic relationships, usually mutual, between these two grasses (Young et al. 2013). Compared to other endophytes (Mycorrhizal fungi and rhizobacteria) these grass endophytes, including *Neotyphodium* and some *Epichloë* endophytes, can be inherited vertically and, thus, passed to future generations easily, making them more useful in agriculture (Kauppinen et al, 2016). The relationship also shows strong host specificity (Young et al. 2013). Certain strains of these endophytes can increase abiotic/biotic tolerance, including protection from herbivory and environmental stresses such as drought, to allow for better competitiveness and growth beneficial to sustainable agriculture (Kauppinen et al, 2016; Young et al. 2013). This symbiosis could lead to a reduction in the use of chemical fertilizers, pesticides and fungicides (Kauppinen et al, 2016). New grass varieties can be cultivated by inoculating the grasses with endophytes (Kauppinen et al, 2016). In the 1980s, endophytes were selected that were nontoxic to grazing livestock and, since then, endophytes are continually selected to improve the fitness of grasses (Kauppinen et al, 2016). Countries such as the United States, Australia and New Zealand have already begun using endophytes in plant breeding in order to improve commercial agriculture; however, Europe has not yet developed endophyte-enhanced grasses (Kauppinen et al, 2016).

Selection of Endophytes

Some endophyte species with a symbiosis with the grasses *Festuca* (fescues) and *Lolium* (ryegrasses) produce secondary metabolites that are detrimental to livestock, leading to negative effects on the economy of many countries that utilize ryegrass and fescue pastures, including the United States, New Zealand and Australia (Johnson et al, 2013; Young et al. 2013). Research once focused on the end products of each of the alkaloid classes, including ergot alkaloids, lolitrem B, peramine and lolines (Young et al. 2013). Endophytes that produce ergot alkaloids (i.e. ergovaline) in tall fescue and perennial ryegrasses can result in heat stress, as well as fescue-foot syndromes (Johnson et al. 2013). Toxic indole diterpene alkaloids (i.e. lolitremes) produced by endophytes also caused ryegrass staggers in many mammals, including cattle, sheep, horses, deer and alpacas (Johnson et al, 2013). It was also discovered that alkaloid peramine was responsible for insect deterrence. Discoveries such as this led to screening of endophytes that were less toxic to livestock while maintaining the advantageous traits, such as the production of peramine (Johnson et al, 2013). Current research into the identification of the genes and gene products that are required to produce alkaloids are still being conducted (Young et al. 2013). For example, endophytes able to produce lolitremes have functional copies of all 11 genes at the LDT/LTM locus, while those not able to produce lolitremes contain no genes or are missing pathway genes ItmG and ItmM (Young et al. 2013). Those capable of producing the alkaloid ergovaline have functional copies of all the genes at the EAS locus (Young et al. 2013).

Because these endophytes are inherited vertically, they can easily be distributed across a pasture, but many naturally occurring endophytes lack the ability to reduce livestock toxicity. Therefore, pure endophytes must be reproduced in culture to produce low or no negative alkaloids (Young et al. 2013). Endophytes must be introduced to endophyte free seed or seeds treated to kill the original endophytes. The new endophytes must then persist in the hosts and transmit to new hosts through seeds to be sold to farmers and ranchers (Young et al. 2013).

Beneficial microorganisms must be produced in mass quantities and applied to crops (O'Callaghan, 2016). Liquids (sprays, drenches and root drips) and dry formulas have been used for inoculation during planting in the soil. However, these are often unsuccessful because of the amount of inoculum needed on a large scale (Le Cocq et al, 2017; O'Callaghan, 2016). The inoculum can also be applied to the seeds to allow for colonization of the seedling roots; however, there are few microbial seed inoculants available. Many studies have reported methods to produce high numbers of microorganisms for research; however, few have been used for commercial purposes (O'Callaghan, 2016).

New endophytes must be tested on large animals before commercial release (Johnson et al, 2013). This process consists of many trials, requiring large quantities of the endophyte, and is very time consuming. Seeds must be tested for quality assurance to ensure no common-toxic seeds are contaminated in commercial seed lines sold, in order to ensure pastures are toxin free. The compounds are also tested to ensure that there are no possible threats to human health. Tests on Lolitrem B and epoxy-janthitrems have determined no indications of danger for human health (Johnson et al, 2014). The high cost of seeds, poor understanding of the long-term consequences of the toxic endophytes, and the climate adaption of grasses with infected toxic endophytes, all have created a slow transition and development of the new technologies (Poore and Washburn, 2013). However, new endophyte strains have created 200 million dollars annually for the New Zealand economy (Johnson et al, 2013).

Commercialization of Selected Endophytes

Perennial Ryegrasses (Lolium Perenne)

Common-toxic (wild-type) endophytes have been shown to protect ryegrass against the insect Argentine stem weevil (ASW) (Johnson et al, 2013). Thus, endophytes strains, that do not cause ryegrass stagger but still produce resistance to pests, such as ASW are being identified. Thus, a few species produce peramine (a deterrent to ASW) but do not produce lolitrem B (associated with ryegrass staggers) (Johnson et al, 2013). Selected endosafe endophytes (*N. lolii*) were inoculated into newly developed superior perennial ryegrasses, resulting in two ryegrass cultivars. Unfortunately, these new cultivars also produced the alkaloid ergovaline that causes heat stress and decreases productivity of livestock. Thus, endophyte strains must produce peramine but not lolitrem B or ergovaline (Johnson et al, 2013). The endophyte, *N. lolii,* strain AR1, was identified and eventually used commercially in New Zealand in 2001. AR1 produced only peramine and protects the plant from both ASW and pasture mealybug (*Balanocuccus poea*). In addition to pest resistance, AR1 were able to produce greater yields than the perennial ryegrass unaffected with endophytes (Johnson et al, 2013). By 2007, 80% of the endophyte-infected seeds were the AR1 endophyte. Farmers untilizing the AR1 cultivars were able to produce 9% more milk because of the reduced toxicity to mammals. AR1 cultivars are exported into Australia, and Chile and are being evaluated in the USA, Europe and Argentina (Johnson et al, 2013). Unfortunately, some insects, such as the Africa black beetle and root aphid, are not deterred by the peramine produced by AR1. However, the endophyte AR37 was discovered with resistance to a wide range of insects, including the black beetle, pasture mealybug, porina (*Wiseana cervinata)* and root aphid (*Aploneura lentisci*). Unfortunately, the AR37 strain has been shown to cause ryegrass staggers in sheep. The demand for insect deterrence led to the commercialization of AR37 in 2007. The only known bioactive compound produced by the AR37 strain is s-janthitrems which may or may not be the compound contributing to the insect resistance (Johnson et al, 2013; Young, Hume and McCulley, 2013). Studies indicate that ryegrass infected with the AR37 strain produced more yields than both the common-toxic and AR1 strains. One study showed that AR37 cultivars ranked highest for dairy cow health, agronomic performance and tiller densities when compared to AR1 and common-toxic strains three years after establishment. However, evidence is inconclusive on the effects of this endophyte on the growth of grasses (Johnson et al, 2013). Selected endophytes, like AR1 and AR37, contribute approximately 200 million dollars each year to New Zealand's economy (Kauppinen et al, 2016).

Tall Fescue (Festuca Arundinacea)

In the United States 8 billion beef cows graze on tall fescue each year (Poore and Washburn, 2013). In addition, many dairy cows, horses and small ruminants graze in the fescue belt. Tall fescue pastures have been known to cause fescue toxicosis caused by the bioactive compound ergovaline including, the cultivar Kentucky 31 tall fescue (Johnson et al, 2013). This and other alkaloid toxins cause over a billion dollars in losses to the economy of the United States because of their effects on growth rate, reproduction and milk production (Poore & Washburn, 2013). The endophyte strain, *N. coenophialum* AR542, does not cause fescue toxicosis because it lacks the EAS genes and, thus, does not produce ergot alkaloids (Poore and Washburn, 2013; Young et al. 2013). This endophyte strain produces loline alkaloids that cause broad spectrum insect deterrence, including the aphid (*Rhopalosiphum padi*), Japanese beetle (*Popillia japonica)* larvae, ASW adults and larvae, fall armyworm (*Spodoptera frugiperda*), corn borer (*Ostrinia nubilalis*), porina *(Wiseana cervinata)* larvae, grass grub larvae (*Costelytra zealandica*), and the large milkweed bug (*Oncopeltus fasciatus*) (Johnson et al, 2013). AR542 and AR584 were even evaluated to determine their ability to effect nitrogen pools and gas influxes from the soil to the atmosphere but there was a lot of variation between stands infected with the endophytes (Young et al. 2013). However, studies do indicate that endophytes are important for the sustainability of tall fescue pastures (Young et al. 2013). Initial and longterm studies have shown that animal performance for this strain was similar to the endophyte-free tall fescue but better than the wild-type endophyte tall fescue cultivars (Poore & Washburn, 2013). Research also indicates that nontoxic cultivars showed increased agronomic characteristics compared to endophyte-free varieties (Johnson et al, 2013; Poore and Washburn, 2013) Cultivars were originally developed in the USA (MaxQ®) and then used in New Zealand and Australia (MaxP®) (Johnson et al, 2013).

Other Sustainability Applications

Crop Production and Horticulture

Livestock owners are not the ones who would benefit from selected endophytes. Endophytes have the ability to increase crop yields and quality of plants for crop production and horticulture (Kauppinen et al, 2016; Lugtenberg, Caradus & Johnson, 2016). Endophytes are able to reduce abiotic stresses, including changes in temperature, salinity and water availability (Lugtenberg et al. 2016). Decreased water availability and soil salinization increases due to climate change and, thus, fungal endophytes with the ability to mitigate these problems impact agricultural plant communities (Lugtenberg et al. 2016). Redman et al. (2011) found that inoculating two rice crop species with class 2 fungal endophytes reduced salt and drought stresses. In addition, plants with endophytes tend to consume 20-30% less water while displaying increased growth rate, yield and biomass. Fungal endophytes isolated from barley were able to increase yields in a previously nutrient deficient barley cultivar by up to 29%, helping to reduce the amount of fertilizers needed (Lugtenberg et al. 2016). Barley, wheat, rice and tobacco inhabited by the endophyte, *Piriformospora indica,* have increased salt tolerance. *P. indica* also increased crop yields with higher nutrient input even at colder temperatures (Lugtenberg et al. 2016). Thus, this endophyte helps reduce stresses due to climate changes, increasing yields and may help crops grow on previously unsuitable land. A powder of *P. indica* is even been developed and used on fields in India called “ROOTONIC” (Lugtenberg et al. 2016).

Endophytes are also able to reduce pathogens in their host plants, including pathogenic bacteria, fungal and protozoa (Kauppinen et al, 2016). For example, *P. indica* increases host tolerance to many root and foliar pathogens. It reduces root disease in crops such as maize, tomato, wheat and barley (Lugtenberg et al. 2016). One study found that *P. indica* colonizes the roots of tomato plants, increases biomass of leaves up to 20% and reduces the severity of verticillum wilt by up to 30%. The endophyte in sugar cane, called *Epicoccum nigrum*, protects plants against many pathogens, including *Sclerotinia sclerotiorum* in sunflowers, *Pythium* in cotton, phytoplasma bacteria in apples, and *Monilinia* spp. in peaches and nectarines (Lugtenberg et al. 2016). Endophytes isolated from *Theobroma cacao* tree have resistance against pathogens, including *Moniliophthora roreri* (causes frosty pod rot), *Phytophthora palmivora* (causes black pod rot) and *M. perniciosa* (causes witches’ broom) (Lugtenberg et al. 2016). Infected plants can also act as buffers beside crops to reduce crop losses in some species (Kauppinen et al, 2016). For example, one study by Shiba and Sugawara in Japan showed that perennial ryegrasses (*Lolium perenne*) infected with *Neotyphodium* endophytes reduced the number of rice leaf bugs (*Trigonotylus caelestialium*) in the fields and, thus, reduced damage to the rice crops (Shiba & Sugawara, 2005). Thus, having grasses as a buffer near farmer’s crops will increase crop yields.

Bird and Wildlife Deterrent

In addition to agriculture, selected endophyte strains act as a deterrent to wildlife such as birds (Kauppinen et al, 2016). Thus, these grass cultivars can be planted on golf courses, airports, sports fields, recreational areas and private lawns to discourage unwanted pests that would normally feed on the grasses (Kauppinen et al, 2016). For example, the commercial endophyte strain, Avanex, has been shown to decrease bird populations near airports, which are hazards to aircraft (Finch, Pennell, Kerby & Cave, 2015).

Sustainable Rural Development

Endophytes have the ability to increase plants' resistance to drought, and thus would be useful in maintaining sustainability of pasture and the forage grasses in rural areas. Endophytes can promote growth, survival, reproduction and competitive dominance and, thus, should act as a natural herbicide reducing the need for synthetic ones (Kauppinen et al, 2016; Saikkonen et al, 2013). One study on meadow fescue cultivars in Europe found that the presence of endophytes in meadow fescue (*S. pratensis, L. pratenses* and *F. pratensis*) slowed weed infestations (Saikkonen, et al, 2013). The study found that endophytes have the ability to reduce both the quantity of weeds, as well as the number of weed species (Kauppinen et al, 2016).

Sustainable Biofuels

Selected endophytes can also be used as a source of renewable biofuels (Kauppinen et al, 2016). These are important because sources of liquid fossil fuels are being depleted (Strobel, 2014). Although most yeasts produce ethanol in order to produce simple sugars, the process is not very efficient and the ethanol is not particularly optimal for internal combustion engines (Strobel, 2014). On the other hand, microorganisms such as endophytic fungi produce other fuel related substances that are more suitable for the internal combustion engine and are renewable. Endophytes produce compounds such as mono-terpenoids, alkanes, cyclohexanes, cyclopentanes and alkyl alcohols/ketones, benzenes and polyaromatic hydrocarbons closely related or identical to those found in diesel. The endophytes are able to produce these products using cellulosic and hemicellulosic polymers found in plant-based agricultural wastes (Strobel, 2014). The discovery of microbes that produce fuel-related compounds is the first step to developing new fuel technology. Secondary metabolites must also be economically feasible and must have engine compatibility (Strobel, 2014). One example of an endophyte, NRRL 50072, that produced multiple hydrocarbons and hydrocarbon derivatives on oatmeal-based agar was *Ascocoryne sarcoides,* originally isolated from *Eucryphia cordifolia* in central Chile (Strobel, 2014). Although the slow growth and low production rates seen by this organism means it would not be commercially feasible, endophytic fungi should be studied in order to find more reasonable options (Stadler and Schulz, 2009). Another important discovery was the volatile organic compounds (VOCs) produced by *Hypoxylon* sp. (CI-4A) isolated from *Persea indica* found on some of the Canary Islands (Strobel, 2014). Many of the compounds had high energy densities potentially useful in mycodiesel fuels. This fungus produces 1,8 cineole which has been added to gasoline and could potentially replace fossil fuel hydrocarbon additives (Strobel, 2014).

Environmental Bioremediation

Many toxic synthetic compounds contaminate the environment through industrial or agricultural pollutants (McGuinness & Dowling, 2009). These compounds pose a health risk to both humans and the environment. Current remediation efforts, including excavation, pump and treat, addition of reactants, incineration, vitrification or transport of contaminants off site, cost 25-50 billion US dollars globally each year (Khan & Doty, 2011). Bioremediation is less expensive, less labour intensive, with a smaller carbon footprint, and is widely accepted by the public compared to traditional methods (McGuinness & Dowling, 2009). Plants extract chemicals from the water, soil and air using energy from sunlight and, unlike engineering technologies, plants do not remove fertile soil in the process (Khan & Doty, 2011). Unfortunately, this leads to potential phytotoxicity, slow degradation and limited contaminant uptake, as well as evapotranspiration of volatile compounds (Khan & Doty, 2011). However, endophytes produce natural products that enhance biodegradation of pollutants by plants (McGuinness and Dowling, 2009). The end products of the toxicity cause plants to remain small; however, endophytes allow for increased growth and nutrient uptake in plants, inhibit pathogens, and reduce environmental stress. Endophytes have been used to treat organic pollutants, chlorinated solvents, BTEX compounds, explosives, petroleum compounds, polycyclic aromatic compounds and, excess nutrients (Khan & Doty, 2011). *Methylobacterium populum* sp.nov. strain BJ001, was used to remove explosives, mineralizing around 60% of RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine) to carbon dioxide in 2 months (Khan & Doty, 2011). Some plants are able to recruit bacteria to remove pollutants and cope with contaminants. Scientists are also genetically modifying endophytes in order to act as bioremediators. For example, Van der Lelie and colleagues genetically modified an endophyte to degrade the toluene component of BTEX, a contaminant found near petroleum and natural gas production sites (Khan & Doty, 2011). Yellow lupine plants with a genetically modified endophyte were able to tolerate toluene better. Heavy metals can also be removed from soils by phytoremediation (Khan & Doty, 2011). For example, an endophyte modified for nickel tolerance allowed plants to increase their nickel concentration by 30% in the roots of *Lupinus leteus*. Thus, endophytes are able to increase plant tolerance, decreasing the release of pollutants into the atmosphere (Khan & Doty, 2011).

CONCLUSION

This review gives a comprehensive overview of the scientific community's knowledge of endophytes thus far. This article emphasizes the vast diversity of endophytes in a variety of temporal and spatial environments and highlights some of the ecological roles of endophytes in their host plants. This review highlights many of the known bioactive compounds produced by endophytes and examines their potential use in both medical and agricultural fields, their role in a sustainable environment as well as stressing some of the important endophytes isolated from native Canadian plant species. Historically, endophytes have been described as an untapped source of biodiversity and bioactive products and the present studies only scratch the surface of possible discoveries and knowledge scientists will learn about endophytes in the near future.

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Chapter 3

The Impact of Climate Change and Variability on Small-Scale Peri-Urban Horticultural Farmers in Domboshawa, Zimbabwe

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ABSTRACT

Zimbabwe is a semi-arid country reliant on regular rains (November-April). Mean annual rainfall is low, and many rivers in the drier parts of the country are not perennial. In the small-scale horticultural sector, irrigation becomes handy. Rainfall exhibits spatial and temporal variability. This scenario is characterized by shifts in the onset of rains, increases in frequency and intensity of heavy rainfall events, increases in the proportion of low rainfall years, decreases in low-intensity rainfall events, and increases in the frequency and intensity of mid-season dry spells. Drought have increased in frequency and intensity. Agriculture is the main source of income for most smallholder farmers who depend on rain-fed cropping and livestock rearing. Adaptation of agriculture to climate variability and change impacts is vital for livelihood. To develop appropriate strategies and institutional responses to climate change adaptation, a clear understanding of climate change impacts on smallholder farmers at farm-level is vital.

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INTRODUCTION

Background to the Study

Domboshawa has been in existence before the colonization of Zimbabwe by the British South Africa Company (BSAC) in 1896. Domboshawa residents have been living as horticultural farmers. However, with the advent of colonization these local people were some of the first to witness "land grabs" by the settlers as their lands are very close to Harare. Resultantly, their cultivated lands dwindled in size due to appropriation by setters. They had to look for alternative livelihood strategies to compensate for the lost land in order to pay for various taxes that were levied on them (Vambe, 1972).

Farmers in Domboshawa have always been predominantly horticultural although with, land grabs, economic challenges and climate change farmers have faced significant challenges. The change in climate is a challenge for both present and future generations. Rainfed agriculture accounts for 80% and 93% of cultivated areas globally and in Sub Saharan Africa respectively and contribute to 62% of the world's staples (FAO, 2004). Africa is particularly vulnerable; its 140 million small holder farmers rely on rainfed farming which is affected by disasters compounded by conflicts, low adaptive capacity, poverty, weak institutions and drought (Rukuni, 2001). The biggest concerns for many in Africa are that yields keep on decreasing while the semi- arid conditions are increasing. (Drechsu & Kunze 2001). In Zimbabwe climate changes has had devastating effects especially in the agriculture sector. Climate change and its associated stressors influence human development through supporting or destabilizing livelihood systems especially that of poor and vulnerable people.

Zimbabwe's Small-Scale Horticulture Sector

Zimbabwe's economy is agro-based. Agriculture contributes more than 20% of the Gross Domestic Product (GDP) and provides an income to more than 75% of the country's 15 million (Zimbabwe Human Development Report, 2017). Three quarters of Zimbabwe's population is rural and their livelihoods are entirely dependent on agriculture. At independence, in 1980 large scale commercial farms (LCF) such as Frupac, Cairns, Favco, Hortico, Hyveldt Horticulture Zimbabwe, Interfresh, Nutresco, Oceanic and Outspan and Selby Enterprises dominated the horticulture sector with production focused mainly on fruits and vegetables. Markets were liberalized beginning the 1990s in line with the structural adjustment programme (SAPs). Small scale horticultural farmers entered the sector and also brought in new varieties. Horticulture refers to the cultivation of fruit, mushrooms, roots and tubers as well as vegetables (FAO, nd). Horticultural produce can be dried, fresh or processed flowers, fruit and vegetables or any product or by-product in processed or non-processed state. Horticulture is a specialised farming activity. Its success depends on a fairly wet climate, good soils, fairly low temperatures and a dependable annual water supply (Muir, 1994). Key enablers of the horticulture sector in Zimbabwe are abundance of land, airfreight space to Europe and other destinations is available, diverse product/ variety mix/ grade mix, dynamism of agriculture, high profile image in Holland and the UK, inputs can be purchased locally, production and marketing groups to maintain quality control, relatively high level of farm management enables production of top quality crops, suitable agro and climatic conditions and well educated, productive and efficient labour force (Matondi & Dekker, 2011).

Zimbabwe has five agro-ecological regions numbered in descending order of agricultural productivity. Rainfall is the main determining factor. Natural Region I receives the highest high rainfall (more than 1000mm) with Natural Region 5 rainfall being below 500mm (Muir, 1994). The poorest households tend to be concentrated in lower potential natural regions. Horticultural production is concentrated around Natural Regions 1, 2 and 3. Changes in climate have expanded arid zones thus leading to shift in Zimbabwe's five main agro-ecological zones. (Unganai & Murwira, 2010). More than 30,000 ha Zimbabwe's land is under vlei vegetable production. Vleis retain moisture in the dry season. In both rural and urban areas almost every homestead cultivates a dryland vegetable plot. Maize is the staple and main crop grown. In the horticultural sector baby marrow, boiled / dried cowpea leaves, brinjals or egg plants butternuts, cucumbers, ginger *(tsangamidzi),* green peppers, jam squashes mufushwa *(nyemba),* rape, sweet potatoes, yams *(madhumbe)* are mainly grown. Growing crops on wetlands is prohibited by the Environmental Management Agency (EMA) although the practice is common.

Generally, horticultural production is located near major urban centres well serviced by a road network for ease of supply of inputs and extension services and for easy transportation and marketing. Prominent small-scale horticultural regions are those close to Harare and mainly in Mashonaland East Province, one of the ten geo- political regions of Zimbabwe. In this province the main horticultural areas are Domboshava, Mahusekwa, Marondera, Murehwa, Mutoko and Uzumba Maramba Pfungwe (Rukuni, et al, 2006). Around Mutare, the provincial capital of Manicaland Province climate is conducive to diversified and specialised farming and horticultural farms are located in Honde Valley, Nyanga, Nyanyadzi and Rusitu Valley. In Bulawayo and Gweru, the horticultural sector is insignificant because these are generally dry and so is Masvingo. The number of farmers in the horticulture sector is not known because data is lacking owing to few studies.

Disruptions to the commercial agricultural sector (subsequent to the introduction of Zimbabwe's Fast Track Land Reform Programme [FTLRP] in 2000), poor governance corruption, bureaucratic delays, inefficiency sector created a situation of economic instability. The FTLRP led to the acquirement of large-scale commercial farms for reallocation to mainly landless local populations especially the blacks (Chagutah, 2010). Poverty levels grew significantly during the FTLRP, and this led to the increased reliance on natural resource exploitation. In addition, it is during this period when temperatures began to increase, erratic rainfall common as well as patterns of recurrent drought. This situation aggravated the suffering of the rural populace who make up more than 75% of Zimbabwe's population. The rural poor mainly depend on climate sensitive livelihoods such as agriculture and this makes them vulnerable to weather perturbations (Twomlow et al, 2008).

Climate Perturbations in Zimbabwe

Zimbabwe is located in a semi-arid region. Its rainfall is erratic coupled with temperature variations. Trends in rainfall patterns show significant spatial and temporal variability. There are shifts in the commencement of the rains, surges in the occurrence and intensity of heavy rainfall events, increase in low rainfall years, decreases in low intensity rainfall events, and increases in the frequency and intensity of mid-season dry-spells (Unganai, 2009). Tropical cyclones and droughts have magnified in occurrence as well as intensity of extreme weather events (Mutasa, 2008). Daily minimum temperatures have risen by approximately 2.6°C over the last century while daily maximum temperatures have risen by 2°C during the same period (ZMS, 2016).

Empirical analysis of rainfall suggests decreasing rainfall trends between 1920 and 2017 (ZMO, 2017). Increased seasons without sufficient rainfall have shown a 5% significant positive trend for December, January and February (DJF) and for March, April, May (MAM). However, for June, July, August (JJA) there is no significant decrease for this longest dry period in the year. Farmers experienced droughts in the 1992/93, 1994/95,1999/2000 and 2001/03, 2007/08, 2016/17 seasons which impacted negatively. In the 1978 /79 season there was excessive rainfall. The 1978 / 79 season was a La Nina season (Stern, 2004). In the 1980s it was easy to predict the coming season, however and the rains have been unpredictable since 1995. There appears to be an increasing trend towards a late start to the rain season, prolonged mid-season droughts, and shorter growing seasons in Zimbabwe with increased droughts, increased floods, late rains, extreme temperatures, dry spells and early rains (Twomlow et al., 2008).

MATERIALS AND METHODS

Domboshawa: A Geographical Brief

Domboshawa is located 26km NE of Harare at 17°S and 31°E. Domboshawa is also known as Chinamhora after the local Shona Chief. It is located in Ward 4 of Goromonzi District in Mashonaland East Province. Administratively, Domboshawa falls under Goromonzi West under Goromonzi Rural District Council (GRDC), one of the nine district councils in Mashonaland East Province. Seventy-five percent of the population rely on farming. There are five wards that make up Domboshawa and these are Mawanga, Munyawiri, Murape, Shumba and Pote (Mashonaland East Provincial Census Report, 2012). In 2012 Goromonzi District had a population of 178,227 people and an area of 2459 km^2 with a population density of 83 people/km^2.

Domboshawa is situated in natural farming regions 2 and 3 on the Highveld of Zimbabwe at 1200 m.a.s.l. The average rainfall ranges from 800-1000 mm per annum. In drought years, however rainfall tends to decrease e.g. in the 1991/92 drought, rainfall was 405mm. Rainfall is seasonal with approximately 90% falling from October to March (Vincent and Thomas, 1962). Temperatures in Domboshawa are generally warm in the summer months ranging from 22 to 30ºC. However, winters can be quite cold (to below18 ºC.) with temperatures dropping down to freezing level especially at night. Horticultural crops need adequate protection in winter to avoid damage by frost. Soils are mainly grained sands and sandy loamy soils which belong to the paraferralitic group of soils (GRDC, 1996). Vegetation is mainly Miombo woodland.

Sample and Procedures

The research design is qualitative / quantitative (mixed methods) in nature and used a case study to enable an in-depth inquiry. The study of climate change adaptation is focused lived experiences and such studies adhere to a philosophical approach of understanding social phenomena which traditionally advocates for the use of qualitative and quantitative data. The main data collection techniques used were household face to face interviews, key informant interviews, semi-structured interviews, structured participant observation and participatory village workshops that involved hazard mapping, rainfall calendar, seasonal/daily calendars, historical timelines, vulnerability matrices and institutional mapping. Triangulation of data gathering was done to build a comprehensive picture of the impact of climate change on horticultural farmers.

Simple random sampling was used to select 45 respondents for the questionnaire. The population registers from the Headmen of each of the five wards; Munyawiri, Mawanga, Shumba, Murape and Pote villages were obtained which constituted the sampling frame. Each entity or individual was selected one at a time and independently therefore ensuring that each entity had an equal chance of being selected from the five villages. Purposive sampling was used to select people or organisations that are working in the area, such as the Catholic Church. Specific method used in the Quantitative approach was the survey. Collected data were categorised into themes for easy analysis.

RESULTS AND DISCUSSION

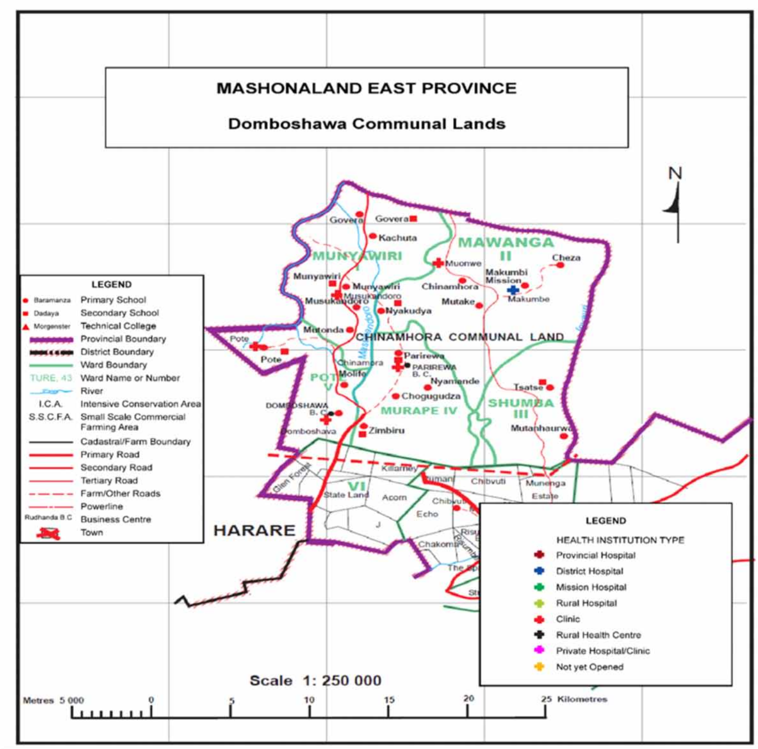
Domboshawa as a Buffer Zone to Harare

Domboshawa has borne the brunt of Harare's meltdown over the past two decades. Domboshawa is very close to Harare, and being a rural area, life is relatively cheap. It is a buffer zone for poor people who cannot afford expensive Harare. In migrants in Harare who fail to adapt find it easier to seek cheaper and alternative accommodation in Domboshawa. Those who live in Domboshawa try to build a home in Harare once they become better off. Rentals are part of the off-farm income for some residents of Domboshawa. Farming continue to be disrupted by economic problems hence not much is coming from tomatoes and onions that used to be the main sources of livelihoods. Young school dropouts and those who completed their high school and tertiary education are expected by the community to leave horticulture for the elderly and the uneducated. Unfortunately, due to the problems highlighted above they continue to try to eke a living from farming and this puts a strain on the already precarious land situation aggravated by low rainfall.

Importance of Horticulture in Domboshawa

Horticulture is very important to the Domboshawa community because it helps to improve their general welfare. This is particularly important because more than 2 billion people in developing countries especially women and children suffer from micronutrient deficiencies (FAO, 2012). Horticultural crops contribute to eradication of global micronutrient crisis, increase in incomes, creation of employment, improvement in food security and nutrition, human health, provision of opportunities for diversification of income as well as the advancement of economic and social conditions of the rural poor, particularly women. Due to the near collapse of Zimbabwe's formal sector more that 90% of Domboshawa's rely on horticultural

Figure 1.
Source: Surveyor General, 2018



farming and this area is arguably one in which low cost irrigation infrastructure has been designed. The area has been electrified in most villages rural electrification has brought in other extra benefits such as night schooling, welding shops and the erection of grinding mills at local shops such as at Mverechena and Munyawiri.

ADAPTATION AND COPING MECHANISMS EMPLOYED BY FARMERS

Smallholder horticultural farmers (SHF) have adopted measures to address climate change and variability. Measures such as crop diversification, soil and water conservation practices, off-farm income activities and integrated crop and livestock diversification have been adopted. Poor infrastructure, inadequate credit facilities as the farmers lack collateral and multifunctional input and output markets have constrained farming activities (Dube et al, 2016). Farmers are adjusting to climate through either adapting and or coping. Adaptation is the ability change to impacts of changing climate in ways that curbs harm or takes advantage of positive opportunities. Adaptation measures in Domboshawa include community-based adaptation, irrigation, migration rainwater harvesting, use of drought-resistant crop varieties, water conserving techniques and water storage. Generally, rainfall is declining in Zimbabwe, focus in the horticultural sector should thus be on techniques to conserve moisture, adoption of better short-season seed varieties and drought-resistant small grains and vegetables (Ministry of Environment and Tourism, 2006) Adaptive capacity is the key determinant to adaptation. Adaptive capacity refers to the potential or ability of a system, region, or community to adapt to the effects or impacts of climate change' (Eriksen, O'Brien & Rosentrater, 2008). The main determinants of adaptive capacity are economic, political and social and natural resources as well as social networks, these problems are deep rooted owing to the serious economic challenges the country has faced from around 2000 to present day. the main stressors tend to be vegetable diseases, limited government capacity to help farmers. famers have a low adaptive capacity due to poverty and marginalisation.

Crop Management

Leafy vegetables are mostly grown as they are an important complimentary dish to Zimbabwe's staple food, maize. An influx of new and improved leafy vegetable varieties were well marketed over indigenous cultivars but this trendy seems to change as explained below. The costs of hybrid varieties at USD10 for less 50 grams of rape seed for example are prohibitive and therefore out of reach of most farmers. In Chinamhora farmers have taken heed of climate change and are now growing local cultivars such as brassica spp (rugare and viscourse). Cultivating indigenous vegetables is relatively cheap as some are easily produced from cuttings. These vegetables can withstand moisture stress for a considerable period of time and respond well to organic sources of nutrients such as cattle manure and compost. Spider-wisp can grow naturally without any need for proper care as compared to hybrid seeds

The harvesting period extends to over one year with some plants growing as tall as 2m. The supply is almost constant throughout the year. There is high demand of these local vegetables at local retail markets. The need to maintain genetic diversity is emphasised as farmers hope to increase their seed banks. The alteration and the timing or location of cropping activities as well as different planting dates are activities done to minimise the impact of climate change e.g. garden crops are increasingly planted in fields which were originally reserved for crops (crop relocation). In one season therefore two crops are grown thus expanding a farmer's opportunities. Famers have also devised new and innovative ways such as integrated pest and pathogen management e.g. the use of black jack to remove aphids from the field.

This is done because pesticides are not only expensive but are an environmental hazard to both people and animals.

In Domboshawa, there has been some decline in agrobiodiversity in farmers' fields. Food security is progressively more dependent on few varieties of crops. The current attention is now focused on "neglected and underutilized crops" (NUCs). These crops are usually left out within the domains of research and policy.

NUCS are crops that have not been previously classified as major crops, have previously been under-researched, currently occupy low levels of utilisation and are mainly confined to smallholder farming areas (Azam-Ali, 2010).

NUCS are also known by other names such as forgotten crops, minor crops, neglected crops, orphan crops and underutilised crops (Chivenge et al.,2015). NUCs are traditional varieties that are nutritionally rich and adapted to risk and marginal environments characterised by high temperatures, low rainfall and few inputs. Sustainable food production is enhanced through the production of NUCS. In Domboshawa the common NUCS farmers are now growing as traditional horticultural produce include e.g. *nyevhe* (spider wisp leaves), also known as *Ulude* in Ndebele, chembere dzagumana (brassica carinata); tsunga (mustard greens); Amaranthus *species*, wild mustard (*Brassica* spp.); sweet potatoes (*Ipomoea batata*), wild melon (*Cucurbita* spp.), taro (*Colocasia esculenta*). Traditionally, these crops have provided dietary support to the local community. Earlier emphasis by extension workers was premised on "major crops" which have well-established seed market systems and markets as well as support from extension. In recent years, NUCS production fits well into the farmers' agenda due to their low input requirements drought tolerance and their resilience in fighting hunger. Traditional leafy vegetables such as Chinese cabbage (Brassica rapa), cowpea leaves (Vigna unguiculata) and pumpkin leaves (Cucurbita spp) are good sources of, fiber, iron and vitamins (Mabhaudhi et al, 2017). These vegetables are used in other parts of Zimbabwe but due to their perceived low values they are marginalised NUCs have always been grown and farmers kept seeds from past harvests. Imported vegetables such as carrots, rape etc. continue to be grown. Traditional vegetables grown which have shown resilience in times of rainfall variability with English and local names (Shona and Ndebele) are shown in Table 1 below.

Other horticultural crops grown include broccoli, cabbage, cucumber, onion, rape, peas and tomato. A typical family cultivates about a hectare of field crops and between 0.25-0.5 ha of 'garden' for vegetables. The gardens are usually located on wetlands (dambos/vleis) for easy access to irrigation water or on land that is permanently wet. With increase in human population and the consequent drying up of wetlands due to overuse, gardens are now located further away as competition for

Table 1. Traditional vegetables grown in Domboshawa

Scientific Name	English Name	Shona Name	Ndebele Name
abelmoshus esculentus	okra	derere	idelele
amaranthus hybridus	green amaranth	mowa guru	imbuya
bidens pilosa	black-jack	nhungunira/ tsine	ucucuza
brassica carinata	cabbage	chembere dzagumana	umbidha yendumba
brassica juncea	mustard green	tsunga	umbhida yendumba
cleome gynandra	spider-wisp	nyeve/runi	elude
corchorus olitorius	jew's mallow	nyenje/gusha	idelele
cucurbita maxima	pumpkin leaves	muboora	ibhobola
cultivars brassica spp	broccoli /kale	rugare	umbidha
vigna unguiculata	cowpea	nyemba	indumba

Source: Field survey (June, 2017)

land intensifies. The farmers backed an empowering policy agenda which supports and buttresses the capacity of rural communities to conserve, produce and utilise indigenous vegetables to enhance food security and augment their livelihoods. Farmers prefer laws that promote local vegetables in terms of production, commercialisation, market linkages and socio- economic empowerment of women.

Farmers are also adapting by creating seed banks for traditional vegetables This is very important to farmers because having the right seeds at the right time is a key factor to production in times of climate disruption this is part of what is called community adaptation. Farmer seed systems and community seed banks provide are essential safety net for cash-strapped, small scale horticultural farmers.

Soil Fertility Management, Water Management and Diversification

In Domboshawa the community is now using barrier hedges along contours to minimize soil erosion as the soils area left bare due to erratic rainfall and wind. Some land that has been left fallow for long especially along water channels is now being cultivated due to population growth. In some parts of Munyawiri and Shumba villages, the community is protecting the soil through agroforestry practices such as rainwater harvesting. In 20% of the cases, water is conserved through the use of drip irrigation. Water is constantly reused; soils are kept moist through mulching. Due to changes in the water table, 42% of the farmers have moved to a new site looking for garden that is well watered, that is along wetlands and some have moved from horticulture production to small livestock production such chicken, ducks and rabbits. These are relatively easy to farm as they are not capital intensive. The initial thrust is to have these small livestock for family consumption although increasingly, they are traded for other commodities and sold to get an extra dollar. Additionally, there is also diversification of income through movement from farming (on farm) to non-farming (off farm) activities.

Pot holing refers to a conservation farming technique that involves making holes in the field. During crop production, inputs such as fertilizers / manure, seed, water and lime are all concentrated in the prepared hole as opposed to being spread over an area in furrow cultivation (USAID, 2000). Related to potholing is conservation basin making of which the basins hold water on one place and these mainly apply to the growing of cabbages. More than 60% of the farmers that they use the method whether the season is good or bad and this tends to concentrate inputs at one place crop residues especially maize stalks are used by farmers for two main reasons 1) as much so as to conserve moisture and 2) these stalks will after a while decompose into manure and therefore farmers will save on buying fertilisers and 3) mulching reduces the rate of weed growth. Winter ploughing is also an adaptation strategy and farmers grow peas and lettuce which grow well under cold conditions. in addition, crop rotation is done so that there are less chances of disease outbreak by avoiding using up all of the soil nutrients (Muchuru & Nhamo, 2019).

One of the techniques that is used by farmers is deep cultivation (greater than 20 cm) which can loosen and 'soften' the soil, giving plants access to deeper soil. Drip irrigation is also widely used in Domboshawa, this is more useful where water is inadequate as water is directed to a plant, as well as the limited pumping costs associated with this irrigation method suitable for small scale farmers who do not have water in abundance. This method does not only save water by directing water to the plant but is also cheaper in terms of pumping costs. Other areas close to the plant remain dry thus reducing weeds and other associated pets. Care should however be ensured to minimise leaching.

Post-Harvest Adaptation

Vegetables are boiled or cooked with oil, tomatoes, onions and other spices, or mixed with meat to make a relish. Vegetables are also dried (mufushwa in Shona) so that they are available off season. Dried vegetables are also a way of reducing losses in times of a glut at the market. Dried vegetables could be a lucrative business if farmers are taught clean ways of drying vegetables. More than 50% of the farmers sell vegetables within and outside Domboshawa. In order to ameliorate the effects of the likelihood of a poor-season-farmers have resorted to improved, low-cost, low technology food processing methods such as solar drying This is in order to preserve vegetables over a long period of time. Framers have also resorted to marketing strategies that include market information systems, enhanced access to market information by SMS text messages and intermediaries. Postharvest losses at the farm, wholesale and retail markets can reach 25 to 50% for vegetables thus farmers are working with handlers in the postharvest sector. This has resulted in farmers investing in simple and low-cost enhancements such as tender handling, protective packages, shade and cooling, cool storage and cool transport.

Role of Middleman

In the Domboshawa context, middlemen refer to those people who help the farmer in the markets, by buying his produce in bulk in order to resale to final consumes, hawkers and vendors. Middlemen or *makoronyera* as they are popularly known in local language emerged in the early 2000, they communicate with runners at Mbare Musika, the largest horticultural market in the residential suburb of Mbare in Harare. Farmers engage them for personal security and as 'buyers of last resort'. Sometimes the market is slow such that farmers fail to sell their produce. Under this scenario, middlemen are engaged in a vickery auction system. Middlemen approach the farmer seeking permission to sell the produce on his behalf by offering him a unit price for the produce to be paid end of day after they remove their margin. Secondly, farmers sell their produce in bulk to the middleman at a discount to the price that will be prevailing at the market. The produce is then removed from the market and stocked elsewhere so that it can be sold outside the farmers' market. Middlemen influence the price of the produce and those who are stationed at Domboshawa Showgrounds appear to make more money than the farmers. They intercept the farmers before they go and sell the wares at Mbare.

Education and Training

One of the main key adaptations of farmer to climate change is education and training and management know how. These are critical in the way farmers adopt new technologies. Farmers need basic education to aid their embracing of new technologies as well as technical, managerial and indigenous knowledge systems peculiar to a defined community (Makwara, 2013; Muchuru & Nhamo, 2019). There are limited number of extension workers in Zimbabwe that are employed such that they cannot cope. Farmers have instead have adopted various ways of gathering weather information which they record on a seasonal basis (Dube et al, 2016). Famers have also established farmer groups which they use for buying inputs as well as for marketing. Forty percent of the famers enrolled in the master farmer certificates in a bid to increase their farming skills. in Domboshawa there is only one EMA employee who is in charge of the whole district of making sure that there is sustainable management of the resources. Zimbabwe can learn from Kenya where extension officers work with farmers by fusing scientific knowledge from meteorological services and indigenous knowledge systems to repackage weather information that can be easily used by farmers. CropMon provides service to for small-scale farmers in Kenya via text short message services(sms) on weather forecasts, e.g. rainfall, temperature; real condition of crops in the fields, limiting factors when crop development is lower than expected and how to reduce these limitations (Onyango et al, 2014).

In Zimbabwe, the curriculum at both primary and secondary school including tertiary education has been revamped in line with science technology, engineering and mathematics of the country's vision of Zimbabwe being a middle-class economy by 2030., elements of climate change have been fully embraced in the curriculum. The university of Zimbabwe is offering a master's degree in agrometeorology. Almost all universities have had students doing doctoral studies on climate change related impacts. In addition, Zimbabwe is in the process of finalizing the climate change policy document which is anticipated to give direction on the way forward with regards to climate change.

ALTERNATIVE LIVELIHOOD OPTIONS IN DOMBOSHAWA

Virtually all families in Domboshawa have some sources of earnings that does not emanate from horticulture. These include remittances and local employment in the form of grinding mill attendants, herd boys and shop attendants. These are referred to as off farm livelihood activities.

Remittances

In Domboshawa the sole reliance on agriculture is impossible under the current land pressures. Remittances have become the lynch-pin of rural investment and household provisioning. The remittances come from family members and other relatives living abroad in countries such as Australia, Canada, UK and the USA as well as from those working in the SADC region in countries such as Botswana, Mozambique and South Africa. Remittances in Domboshawa cannot be officially quantified because there are no such mechanisms to capture those statistics but 95% of the respondents said they receive remittances. Remittances are usually sent during the holidays periods that is around Christmas, New-year, Easter and Heroes holidays. In between these periods remittances are minimal. Among those who receive remittances, 10% decided to completely stop horticultural farming citing shortages of water and land due to an expanding population. The truth is that they can live on remittances alone.

Stone and Wood Carving

Woodcrafts vending, wood and stone carving are very common in Domboshawa. The woodcraft industry increased steadily since the late 1980s. Both local and external tourists came in large numbers to visit the Domboshawa Monument and Hill as well as the Ngomakurira Hills. A curio shop was established near the interpretive centre at the monument. Factors that up surged demand in the woodcraft industry included (1) the increased demand by tourists; (2) the need by rural households to find extra cash income sources apart from horticulture; and (3) availability of strong tree species such as teak. These tree species have since declined due to deforestation to clear land for agriculture and settlements as well as climate change and variability. In Domboshawa selective use of certain species for carving has driven some species such as *Pericopsis elata* (African Teak), as well as *Brachystegia spiciformis* (musasa) into extinction. With its multiple importance to humans, animals and the environment, Musasa is widely used for fuel, both as charcoal and firewood, beehives and general construction. *Julbernardia globiflora* (munhondo) uses are many. Root decoctions of *munhondo* are drunk for the treatment of depression and stomach problems. Bark fibres are chewed for constipation, tannin from the bark is used as a laxative while decoctions of the bark are dropped into the eye as a cure for conjunctivitis. The leaves are rubbed into scarifications after a snake bite. Traditional healers use these concoctions to cure their patients. Leaf litter is used to improve soil fertility. The plant is a bee forage, yielding honey of very high quality. The inner bark is a rich source of fibre for string and rope in construction as well as for beehives, containers, seats and doors. Bark fibre is used for making warm and pliable ‘gudza’ cloth (a kind of blanket), storage bags and beer strainers. Apart from woodcraft there is also stone carving where pieces of rough natural stone are shaped by the controlled removal of stone and some of the products from thereof include human beings, animals and any types of carvings and sculpture sold along the highway as well as at Domboshawa Hill and Monument.

Broom Grass Collection, Crochet Ware and Pottery

Pottery is a form of art depicting culture. Pottery generally refers Zimbabwe is a semi-arid country reliant on regular rains (generally November to April). Mean annual rainfall is low and many rivers in the drier parts of the country are not perennial.

In the small scale horticultural sector irrigation becomes handy. Rainfall exhibits spatial and temporal variability. This scenario is characterized by shifts in the onset of rains, increases in frequency and intensity of heavy rainfall events, increases in the proportion of low rainfall years, decreases in low-intensity rainfall events and increases in the frequency and intensity of mid-season dry-spells. Drought have also increased in frequency and intensity in the country. Agriculture is the main source of income for most smallholder farmers who depend on rain-fed cropping and livestock rearing in Zimbabwe. Adaptation of agriculture to climate variability and change impacts is vital for livelihood. In order to develop appropriate strategies and institutional responses to climate change adaptation, a clear understanding of climate change impacts on smallholder farmers at farm-level is vital.

Keywords here include adaptation, climate change, coping, livelihoods, off-farm, on- farm perception of anything made out of clay which has been fired and heated through a certain temperature. Pottery perhaps forms one of the oldest forms of off-farm livelihood options especially by women. In Domboshawa, pottery is slowly gaining ground as one of the off-farm income generation due to some problems highlighted in the horticultural industry. A clay pot depending on size fetches between 10-15USD. Clay is collected from specific layers which occur in the sub soil on relatively wet areas along vleis and dambos. These areas are increasingly becoming scarce as a result of erratic rainfall thus threatening the livelihoods of women who mainly depend on this activity. Men and sometimes women use clay to make farm bricks, a thriving industry in Domboshawa due high demand for bricks locally and around Harare. Clay pots are used on numerous occasions and purposes such as gifts, to hold grains, water, preparation of food, brewing of beer among others and are popular within and outside Domboshawa. The decoration of kitchens is made colorful and beautiful by the use of pottery. In times of dire need, women exchange clay pots for grain to feed their families. Going along with pottery is broom grass collection. Broom grass is found in wetlands. Broom grass sells for 3 to 5 USD depending on the size of bundle. It is an important non-timber forest product (NTFP). Broom grass harvesting is being threatened by overexploitation as women seek more livelihood opportunities. Wetlands that are used for horticulture are the ones were clay and broom grass are collected hence there are always competing interests which in some cases lead to conflict.

Crocheting is an art which involves a process of creating fabric by interlocking loops of yarn, thread, or strands of other materials . In Domboshawa, crocheting is mainly a domain for women. Crotchets are displayed at Ngomakurira, Domboshawa Hill and Monument and along the highway leading to these tourist resort centres as well as in shops e.g. at Showground and Mverechena. Crocheted goods include doilies, dresses, hats, shirts and table mats. Thirty percent of the women involved in crocheting reported that they sell some of their wares to Harare and as far afield as Botswana and South Africa. In turn, they bring in forex and goods from these countries for resell.

Menial Jobs Petty and Commodity Trading

Apart from horticulture, almost all people are also involved in informal trade activities such as petty trading in local products such broom grass, local arts and crafts as well as imported products. Asset stripping is common in times of drought, it involves the sale of assets e.g. livestock, houses, household utensils and farming equipment or barter trading for food. Trading was mainly common in drought years although it is currently a daily activity. Second hand clothes and marketing of goods imported from Botswana, Mozambique and South Africa are commonly known locally as mabhero (bales of second-hand clothes) a preserve for women. Men are occasionally involved in selling of crafts and illegal sale of cannabis (mbanje). Trading is highest at Showground (with easy access to Harare and Bindura), with 21% of households involved, next highest is Mverechena and other isolated business centres such Mungate, Makumbe and Shumba.

Menial activities are on the increase due to poverty and urban expansion. These activities are mainly referred by street lingo as *kukikiya* which *means so long we survive.* There is always barter trade occurring in the community e.g. those in grain rich areas exchange maize with a variety of wares, which may include hoes, tins for fetching water, sweeping brooms, second hand clothes and household utensils. The grain they get in such exchanges is used to sustain the household food requirements. Begging is common at major centres such as Mverechena and Showgrounds. Those involved in begging usually approach people whom they think are better off, sing local verses, which indicate hunger and or destitution. In return, for the music the host gives the beggar a bowl of food or some grain if it is the community or some money or food if this is at the local businesses centre.

Due to the proximity of Domboshawa to Harare, some people (48%) work mainly in Harare and its neighboring suburbs such as Borrowdale, Hatcliffe and Highlands doing menial jobs such as house maids, car washing and brick moulding. Casual labour activities in Domboshawa include, domestic work within the villages, general hand, weeding, groundnut picking (from dried harvested plants), and thatching houses and even selling ones' labour in exchange of money or grain. Thirteen percent of the households undertook casual labour (working for civil servants, setting up of small businesses (shops, hair salons) in the villages. Other menial activities rampant at business centres include prostitution and gambling. As a result of liberalisation of prostitution a number of girls are seen flouncing their bodies at business centres especially during the weekends. The number of people involved in this activity could not be quantified because prostitution is shrouded in secrecy since this is a communal area where community values *(Ubuntu)* are held in high esteem.

Food Handouts and Food for Work Programmes

Although farmers work hard to earn a living, in drought years, food-for-work programmes organised by local kraal heads and the Village Development Committee are common. Food handouts are given to community in times of drought. However, the current thinking is that handouts promote laziness and dependency. There is need to step up life empowerment programmes and move away from giving food handouts. Capital for income generating projects instead of food packs or other donations will go a long way in uplifting Domboshawa. Villagers complained that food handouts are politicised although they are donated by multilateral organisations such as the World Food Programme (WFP). Food-for-work programmes transform the community, instead of government dishing out freebies, the community comes in by working to rehabilitate roads, tending to nutrition gardens and water source rehabilitation projects. Those involved work about four hours per day repairing roads and schools among other activities. Rations are given on a pro rata basis to the days worked.

Wealth Obtained From the Natural Environment

Natural resources are an alternative source of livelihood for poor people. In Domboshawa the local rely on common property resources(CPRs) as shown in Table 3 below. The table shows the various resources available, their main uses and users as well as issues surrounding a given resource. CPRs are goods that are collectively owned with a particular community arrangement regulating the conservation, preservation, maintenance, and consumption of a common-pool resources. These resources are available to all although they are increasingly regulated by the Environmental Management Agency (EMA) with the help of agricultural extension officers and traditional leadership in Domboshawa. Anthills are used for fertilizing the soil dug and applied to land to increase soil fertility especially by the poor but increasingly by all people due to steep prices of fertilisers However due to net migration there is generally lack of labour and transport and equipment such as scotch carts and cattle. This is one of the major barrier to use soils from the anthills.

Wetlands provide reeds for basket making and rice cultivation grown in vleis and dambos Availability of wetlands is related to rainfall amount. Reeds are also obtained for making mats access to reeds is a determined b labour and transport. Rice is also grown on wetlands albeit on a small scale. Free ranging cattle and goats in wetland areas mean that cultivators must guard their crops crop. Clay is mainly used for making bricks-making and pottery. Most households make their own bricks. There a general decrease in the amount of clay available due to wetland degradation mainly caused by climate change in the form of erratic rainfall and human settlement encroaching in these areas. Water is mainly used for small-scale irrigation, watering livestock, domestic use and beer brewing. Water is becoming increasingly scare due to climate change as well as the sinking of boreholes of which a number are broken. Dams and rivers are silting due to stream bank cultivation.

Grasslands and vleis provide grazing for cattle, goats, donkeys as well as thatching grass for houses and granaries. However, these areas have also declined in size due the sale of best quality grazing land by unscrupulous kraal heads. Wild foods provide 'relish' trapped by adults as a coping strategy to household food security and income through sale. Leaves and insects as well as game animals and wild fruit trees are harvested. Lack of labour is key barrier to access. Wood is used by carpenters to make implements, furniture carving and construction households and leaf litter is used to provide mulching. Firewood is used by households although increasingly there is use of electricity and liquid petroleum gas (LPG). Wood is also used by blacksmith to make charcoal while Brickmakers use wood to burn bricks though they are now mainly using coal for this purpose.

MULTIPLE STRESSORS

Although farmers use local resources as explained in 5.6 above to enhance their livelihoods, they face risks both climate and non-climate such as droughts, floods, macro-economic conditions (Zimbabwe has undergone serious economic challenges since 1999 to present day, challenges attributed to the land reform programme that the government undertook) crop failure, crop and livestock pests and diseases, input supply and pricing fluctuation, among others. The detailed micro and macro level constraints that affects Domboshawa farmers are explained in Table 4 below.

CONCLUSION

Climate change is a multi-faceted concept which occurs in conjunction with other multiple stressors. The effects of climate change are exacerbated by variables such as biophysical, cultural, moral, political, socio-economic and technical aspects. There are a number of factors that influence the vulnerability of small-scale horticultural farmers to climate change in Domboshawa. Some of these factors include but are not limited to conflict, dependence on climate-sensitive resources, gender inequality,

Table 2. Micro and macro constraints to horticultural farming in Domboshawa

Constraint	Explanation
A flooded market	Currently, horticulture faming in Zimbabwe is not profitable because the market is always flooded. This situation was exacerbated by the fast track land resettlement programme. Farmers who live within a radius of 150 km sell their produce at Mbare Musika leading to a glut.
Deteriorating water levels	Water is increasingly becoming scarce in Domboshawa due to siltation of rivers and erratic rainfall pattern. The situation becomes dire because of competing uses of water such as domestic and brick moulding
High cost of living	The current meltdown in Zimbabwe has meant that farmers opportunities for future investment in the horticulture sector are gloomy. There are very few if any profits obtained, hence further investment in the sector is nil or very limited.
Expanding population	Domboshawa is a buffer zone for Harare. In the 1980s a typical family cultivated between 0.25 – 0.5 ha of 'garden' for vegetables but this has been significantly reduced to less than 0,1 ha in some cases .Some unscrupulous village heads are in the habit of selling pieces land
High cost of input	The prices of inputs such as fertiliser, seed and chemicals is so high such that farming becomes a non-profitable venture e.g. a 50kg bag of fertiliser costs about USD 50. It will take in some cases a month for a farmer to realise a profit of this margin .
Lack of distribution networks	The system of intermediaries between the farmer and the final users, disadvantages the farmer because they cannot decide the price. Increasingly this role has been undertaken by middlemen who are so corrupt and cunny, they can buy all produce from farmers at the lower price and on reaching the market get high profits due to overcharging .
Perishability of horticultural produce	Despite horticulture having been established a long time ago as an important activity, there are no refrigeration facilities such that produce quickly tends bad should it not be sold. Losses are thus always incurred
Poor market prices of vegetables	Quality packaging by competitors such as established entities means that produce from Domboshawa is not sold at up market outlets such as Food Lovers where prices are on the steep side to fetch significant profits
Poor water lifting equipment	Farmers usually use the bucket system for irrigation, they cannot buy sophisticated equipment because the glut at the market renders farming unprofitable.
Price wars within the industry	Rivalry within the industry has caused price wars and some farmers have opted for alternative livelihood strategies such as petty trading crocheting, wood carving among others. in case of price wars, it is the farmer who suffers.
Untimeliness of weather forecast information and Reduced access to weather forecasting information.	Climate and weather information is not specifically tailored to, it covers a wide area and Domboshawa is usually bunched with Harare in terms of information dissemination

Source: Adapted and modified from Proctor et al, 2000

HIV/ AIDS, inequitable land distribution, insecurity, low educational levels, poor health status and poor infrastructure. For sustainable adaptation strategies, recognition of multiple factors that affect agriculture should be acknowledged. There is need for Agricultural research support leads to appropriate agricultural innovations and development of new livelihood options This study underscored the importance of understanding cognitive and normative aspects of the local communities to appreciate climate vulnerability and change.

Climate change has impacted across the whole spectrum of the Zimbabwe society but to date there is no clear climate change response strategy or climate change policy in Zimbabwe. Interestingly some legislative and programmatic adaptation are scattered across government development policies in the agriculture, disaster management, environment and natural resources management sectors. A well-funded Meteorological Services Department working with farmers and Agritex has the potential to disseminate weather information timely and in a simple manner .Once this is done farmers will be able to build their resilience through use of local genetic diversity, soil organic matter enhancement, multiple cropping or polyculture systems, and agro-forestry systems and mulching and adoption of new and improved varieties, soil and water conservation techniques such as terracing, conservation tillage and simple water harvesting techniques. Livelihood diversification in the form of off farm activities such broom grass collection and petty trading are also equally important. In general, a clear climate change policy which encompasses fragmented pieces of legislation and strategies will go a long way in the rejuvenation of various adaptive responses at a local and national levels.

RECOMMENDATIONS

There is need to educate horticultural farmers on climate change impacts so that they are able to design adaptation strategies that take into cognizance existing local level knowledge (including indigenous knowledge) and practices on land and water management so as to boost agricultural production. While there are multiple stressors that confront farmers, climate variability and change remain the critical ones hence there is need to develop climate awareness raising campaigns aimed at government (especially legislators), civil society and the general public (especially farmers). Overall, Zimbabwe requires a national climate change framework to guide coordinated action and investment and this may include climate proofing strategies.

The Zimbabwean government should take lead in developing alternative livelihood strategies such as the creation of small to medium scale industries at rural service centres so that farmers do not suffer when agriculture fails. More attention must therefore be paid to the institutional challenges facing effective climate governance to ensure that future policy will be planned and implemented successfully so as to minimise the negative impacts of climate change. In the same vein devolution should be speeded up so that rural areas are well developed.

Zimbabwe has opportunities which it can leverage to develop the farming sector. With some effort and fiscal discipline, local resources can be used to create fiscal space for sustainable development. This can also be done by encompassing strict measures which prohibit the illicit financial outflows to the tune of US$1.8 billion annually. The informal economy (90%) could be regulated so that it helps to boost fiscal space. Young people should be incorporated fully in the economy through skills development under current initiatives such as the STEM (Science, Technology, Engineering and Mathematics) in promoting agriculture. The Ministry of Primary and Secondary Education has been proactive in this respect because agriculture is now taught and examinable in primary schools as a separate subject. This scenario is pertinent because Zimbabwe's economy is agro-based.

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Chapter 4
Reduction of Carbon Intensity:
Rhetoric or Reality?

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ABSTRACT

Global warming is unequivocal and almost certainly caused by recent human activities that have increased the greenhouse gas (GHG) emissions. Emissions reductions of carbon dioxide and cumulative carbon emissions from energy consumption have created widespread concern of various government agencies, scientific circle, and the general public. The states and the international community are simultaneously struggling to address climate change. Impacts of carbon emission are inevitable and there is a long debate as to who bears the losses incurred due to the carbon emission. Both the developing and the developed economies need to reduce their CO_2 *intensity significantly for stabilizing the Earth's climate at no more than a 2°C temperature rise. However, for the sake of health, safety, and environment, the supply of oil and gas as well as emission of carbon need to be operated in an environmentally sustainable manner so as to avoid environmental harms.*

INTRODUCTION

Global warming is unequivocal and almost certainly caused by recent human activities that have increased the greenhouse gas (GHG) emissions. Despite the 1992 UN Framework Convention on Climate Change and the 1997 Kyoto Protocol, the GHG emissions continue to rise worldwide. The public, media and governments have devoted considerable attention to the issue of climate change and the warming of average global temperatures being caused due to increases in greenhouse gas (GHG)

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concentrations. The states and the international community are simultaneously struggling to address climate change.

The amenities of human lives like water and sanitation, food production and storage, light, heating and cooling, transportation, medical devices, pharmaceuticals, clothing, building materials greatly rely on the supply of oil and natural gas. Oil and gas are important to meet the growing demand of energy, and eventually support economies around the globe. For the sake of health, safety, environment, the supply of oil and gas as well as emission of carbon require to be operated in an environmentally sustainable manner so as to avoid environmental harms.

Climate change will have an impact on prospects for sustainable development. Undeniably, the effects of climate change cause sufferings in human lives. Therefore, international climate policy, environmental law, and human rights law have gained popularity. Impacts of recent climate change on natural and human systems are increasingly detected at the local, regional and global level (Cramer et al. 2014).

INDUSTRIAL DEVELOPMENT AND EMISSION OF CARBON

Emissions reductions of carbon dioxide and cumulative carbon emissions from energy consumption have created widespread concern of various government agencies, scientific circle, and the general public (Wen et al., 2014). CO_2 emissions of China have surpassed those of the United States and became the highest in the world in 2006 (Huang et al., 2011). Non-fossil energy consumption to primary energy consumption is predicted to be 15% or so in China at around 20 percent. The proportion of secondary industry increased from 40.05% to 51.99% in 2000–2010, and the proportion of tertiary industry was stable around 40%. The proportion of secondary industry of China was to be forecast to be 48.7% by 2050 (Zhao & Tao, 2011). The Republic of Korea also announced a voluntary action plan to reduce greenhouse gas emissions by 37% from the business-as-usual (BAU) level of 851 million by 2030 (World Energy Outlook, 2015).

In particular, Korea's construction industry accounts for 48% of the total material consumption and 40% of the national energy consumption. In terms of CO_2 emissions during the production of construction materials, in addition, the construction sector accounts for about 25% (Cho & Chae, 2011). There has been a rising demand for certification on carbon emissions and reduction in construction materials and inventories in Korea (Korea Institute of Civil Engineering and Building Technology, 2016). In addition, the development of carbon reduction technologies has been active, and diverse low-carbon products have been produced (Korea Environmental Industry & Technology Institute, 2016). Green building contributes to the reduction of GHG emission (Liu et al. 2016). 85% of total carbon emissions may be caused depending on the type of building due to the use of heating and cooling energy and electrical facilities (Asdrubali et al., 2013).

Although identifying an explicit resolution of climate equity or fairness is still difficult under the UNFCCC at present, a basic set of shared equity principles has been applied in sharing mitigation efforts (Höhne et al., 2013). The IPCC AR5 (Clarke et al., 2014) has grouped existing effort-sharing schemes into six categories, according to specific interpretations of equity principles on which they are based, including responsibility, capability, equality, responsibility–capability–need, equal cumulative per capita emissions, and staged approaches. These six categories have been used to highlight all plausible equity principles or fairness arguments to share efforts in the international community (Pan & Teng, 2017). Although the equity principle has been elaborated in various climate decisions, it is debatable in political negotiations (Klinsky & Winkler, 2014).

IPCC AR5 has also listed another category called “cost-effectiveness”, which uses allocations emerging from an equal carbon tax worldwide that can be used as a reference to compare other allocations (Pan & Teng, 2017). Hence, allocations resulting from these effort-sharing categories could facilitate in providing ranges and boundaries of countries’ fair contributions in the future (Robiou, 2017).

Current climate negotiations emphasize on the mitigation targets of the countries through the INDCs. Comparing the INDCs with allocations as calculated from an effort-sharing framework, is still worthwhile to clarify whether and to what degree countries’ INDCs meet their fair contributions aroused by different equity principles (Pan & Teng, 2017).Emissions Gap Report of the United Nations Environment Programme (UNEP) has demonstrated that the global emissions gap between the INDCs and the least-cost 2°C pathways is about 12–14 $GtCO_2eq$ in 2030 (UNEP, 2016). Temperature rise well below 2°C (with a likely chance) would imply that global carbon emissions need to become zero by 2060–2075 (UNEP, 2016).

IMPLICATION OF THE REDUCTION OF CARBON INTENSITY

Current atmospheric concentration of CO_2 is nearly 450ppm. According to an analysis of the Potsdam Institute for Climate Impact Research (PIK), stabilizing atmospheric CO_2e concentrations at 450ppm offers up to 50% chance of achieving the 2°C maximum temperature rise. GHG emissions reductions is a hallmark of every climate change regulatory scheme at the international, national, and sub-national levels of government (Engel, 2007).

Global warming in the past 50 years has raised average temperatures to above the range of the current Holocene period, when 126,000 years ago sea level was 6 to 9 meters higher than today (Hansen et al. 2017). Average global surface temperature in 2016 reached the highest level in the instrumental records, at 1.24° C above the 1880-1920 baselines (Hansen et al. 2010). Although temperatures in 2016 were partly boosted by the 2015-16 El-Niño weather events, warming in the Arctic was closer to 3° C above average (Hansen et al., 2016). Evidence for the warming of the Earth's atmosphere and ocean system was unequivocal, and it was extremely likely that human influence was the dominant cause of global warming due to atmospheric greenhouse gas (GHG) emissions (IPCC, 2008).

Unprecedented summer heat-wave of 2003 in central Europe was coincident with an increase in the mortality rate far more than usual. Emissions of greenhouse gases, black carbon, and other aerosols almost certainly have contributed to the observed long-term trend in reduction of summer ice extent by affecting the surface energy budget (Serreze & Barry, 2011). Low income countries have seen the highest losses in terms of casualties due to extreme weather events (Strömberg, 2007) typically have not had the means to have deployed long-term monitoring systems, and other serendipitous proxies may be lacking (Huggel et al., 2015).

Global warming caused by emissions of greenhouse gases has become one of the world's major environmental problems and draws much attention (Fan et al. 2015). Share of coal, the dominant energy in China, have declined very slightly in recent years, but have subsequently increased in 2007 and 2011 (National Bureau of Statistics of China, 2014). Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) has confirmed that global climate change has been an extremely severe challenge faced by humanity (IPCC, 2013).

The 2008 UNDP report considers the 2°C temperature rise as a reasonable and prudent long-term objective. The Conference of Parties (COP)-21 held in Paris on December, 2015 also acknowledged the same and accordingly put emphasis on achieving 2°C temperature rise. To this end, CO_2 emissions worldwide need to be reduced by around 50 percent by 2050 to achieve the target.

Since the 1990s, the energy consumption of industry per unit of value added in developed countries, has fallen by around 1.3% per year on average (once adjusted for structural changes), but at a lower rate than the average reduction of 2.8% per year during the 1970s and 1980s[1]. Industrial processes are highly energy intensive and account for one-third of global energy use. Around 70% of this energy is supplied by fossil fuels, and CO_2 emissions from industry make up 40% of total CO_2 emissions worldwide (Brown et al., 2012).

Improvements in energy intensity have increased total production, whereby energy consumption and CO_2 emissions have continued to rise dramatically. Demand for manufactured goods is expected to be at least doubled by 2050 relative to 2006 levels, and, if industrial emissions remain unchecked, total CO_2 emissions are projected to increase by up to 90% by 2050 compared to 2007 (IEA, 2010).

More than 170 nations agreed to limit fossil fuel emissions to avoid dangerous human-made climate change, as enunciated in the 1992 Framework Convention on Climate Change. In the Paris Agreement, all parties to the UNFCCC have agreed on an overarching goal to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to below 1.5°C above pre-industrial levels (UNFCC, 2015).

Currently, China is the largest producer of ammonia, cement, iron and steel, and methanol. Production in China will follow OECD trends, likely leveling out by 2050, as its economy shifts towards the services industry. By comparison, industrial activity in India, Africa and the Middle East is expected to increase by around 150% by 2030 and 300% by 2050, compared to current levels (IEA, 2010). Overall, the global demand for industrial products is expected to be more than doubled by 2050 (Allwood et al., 2010).

Global dependence on fossil fuels contributed to the excessive release of CO_2 into the atmosphere since the mid-19th century. Currently, energy-related GHG emissions, mainly from fossil fuel combustion for heat supply, electricity generation and transport, account for around 70% of total emissions including carbon dioxide, methane and nitrous oxide. Extraction and combustion of mineral resources like oil, coal, peat, and natural gas create excessive release of carbon into the atmosphere.

Privatization of the electricity sector has ensured energy supply and provided cheaper energy services in some countries. Lack of security and higher world-energy prices constrain efforts to accelerate access to modern energy services that would help to decrease poverty, improve health, increase productivity, enhance competition and thus improve their economies. Without effective mitigation; energy-related carbon dioxide emissions will rise from 26.1 $GtCO_2$ (7.2 GtC) in 2004 to around 37–40 $GtCO_2$ (11.1 GtC) in 2030 (IEA, 2006). Cost-effective means of reducing carbon emissions need to be applied to decrease the rate of atmospheric concentrations.

Natural gas and nuclear gained an increased market share after the oil crises in the 1970s and continue to play a role in lowering GHG emissions, along with renewable energy. In case global energy demand continues to grow along the anticipated trajectory, by 2030 the investment over this period in energy-carrier and conversion systems will be over 20 trillion (1012) US$, being around 10% of world total investment or 1% of cumulative global GDP (IEA, 2006). Therefore, investment in energy-supply systems of around US$830 billion will be required in a year, and there will be a shift towards more sustainable energy systems.

Ecological implications of energy supply result from coal and uranium mining, oil extraction, oil and gas transport, deforestation, erosion and river-flow disturbance. Policies and measures aimed at increasing sustainability through reduction of energy use, energy-efficiency improvements, switching from the use of fossil fuels, and reducing the production of process wastes, will result in a simultaneous lowering of GHG emissions and reduced air pollution.

Although regulations to limit CO_2 emissions could be incorporated as command and control clauses in most of the existing legislative schemes, no country has so far attempted to do so. Rather, emissions trading have emerged as the preferred method of effecting global GHG mitigation, both within and outside the auspices of the Kyoto Protocol (Sloss *et al*., 2003). Emissions of greenhouse gases, black carbon, and other aerosols almost certainly have contributed to the observed long-term trend in reduction of summer ice extent by affecting the surface energy budget (Serreze & Barry, 2011). Russian Federation is endowed with very high fossil fuel reserves representing 34%, 12% and 20% of world deposits of natural gas, crude oil, and coal, respectively. The energy sectors are logically dominated by fossils fuels, and are importantly used for exports (SDSN & IDDRI, 2014).

Global emissions have accelerated and new efforts are underway to massively expand fossil fuel extraction (Johanson et al., 2012). They are extracted by drilling to increasing ocean depths and into the Arctic, squeezing oil from tar sands and tar shale, hydro-fracking to expand extraction of natural gas, developing exploitation of methane hydrates, and mining of coal via mountaintop removal and mechanized long-wall mining. Global community is aimed at preventing the negative impacts of climate change, as manifested by drought, heat waves, flooding, and sea level rise. It is a good sign that since 2010 renewable-power generation grew by more than 30%, and is forecast to grow by another 30% by 2020. Again, innovative low-carbon transportation technologies have gained momentum and the same reflects the chances for low-carbon emission in the coming decades. Risk assessments of GHG emissions should ensure the development of country-specific responses to prevent and mitigate the damaging consequences on the social, economic and environmental fabric of the country.

IMPACTS ON CLIMATE CHANGE

Climate change is the presence of increasing carbon dioxide (CO_2) in the atmosphere due to emissions from fossil fuel. Atmospheric CO_2 has increased rapidly to a level not seen for at least 3 million years (Beerling & Royer, 2011). Global warming induced by increasing CO_2 will cause ice to melt and hence sea level to rise as the global volume of ice moves toward the quasi-equilibrium amount that exists for a given global temperature (Foster & Rohling, 2013).

Long-term global warming trend is predominantly caused by the increase of greenhouse gases. Increase of ''greenhouse'' gases such as CO_2 makes the atmosphere more-opaque at infrared wavelengths, causing infrared radiation to space to emerge from higher, colder levels, which thus reduces infrared radiation to space. The resulting planetary energy imbalance, absorbed solar energy exceeding heat emitted to space, causes earth to warm (Hansen et al., 2013).

Global dependence on fossil fuels contributed to the excessive release of CO_2 into the atmosphere since the mid-19th century. Currently, energy-related GHG emissions, mainly from fossil fuel combustion for heat supply, electricity generation and transport, account for around 70% of total emissions including carbon dioxide, methane and nitrous oxide. Extraction and combustion of mineral resources like oil, coal, peat, and natural gas create excessive release of carbon into the atmosphere.

Ecological impacts of recent climate change are severe on the planet. Global warming process of the 21st century exceeds the natural variability of the past 1000 years. The growth rate of fossil fuel emissions increased from 1.5% per year during 1980–2000 to 3% per year in 2000–2012, mainly because of increased coal use (Boden et al., 2012). Indiscriminate activities of humans cause changes of atmospheric composition of the earth and eventually drive to the future climate change.

Global temperature and energy imbalance of the earth are most useful parameters for the measurement of global climate change and for the considerations to stabilize global climate. Climate impacts are enormously rising with devastating effects on the environment and planet as well as affecting the lives of humans. Arctic sea ice end-of-summer minimum area, although variable from year to year, has plummeted by more than a third in the past few decades, at a faster rate than in most models (Stroeve et al., 2012). The Greenland and Antarctic ice sheets began to shed ice at a rate, now several hundred cubic kilometers per year, which is continuing to accelerate (Hanna et al., 2013). Mountain glaciers are receding rapidly all around the world (Rabatel et al., 2013). Therefore, availability of seasonal freshwater is hampered in major rivers. The hot dry subtropical climate belts have expanded as the troposphere has warmed and the stratosphere cooled (Liu et al. 2012), contributing to increases in the area and intensity of drought (Dai, 2013) and wildfires (Westerling et al., 2006). Because of ocean warming and acidification of ocean caused by the increasing dissolved of CO_2, abundance of reef-building corals is gradually decreasing. More than half of all wild species have shown significant changes in where they live and in the timing of major life events (Poloczanska et al., 2013). Mega-heat-waves, such as those in Europe in 2003, the Moscow area in 2010, Texas and Oklahoma in 2011, Greenland in 2012, and Australia in 2013 have become more widespread with the increase demonstrably linked to global warming (Hansen et al., 2012).

CARBON EMISSION AND ENVIRONMENTAL IMBALANCE

Carbon from fossil fuel burning will remain and the same would affect the climate system for many millennia, ensuring that over time sea level rise of many meters will occur –tens of meters if most of the fossil fuels are burned (Foster & Rohling, 2013). Continuous rise of sea level would cause loss of hundreds of historical coastal cities worldwide with incalculable economic consequences, create hundreds of millions of global warming refugees from highly-populated low-lying areas, and thus likely cause major international conflicts (Hansen et al., 2013).

About 500 million residents of North China experienced during the 1990s a loss of more than 2.5 billion life years owing to the added air pollution, and an average reduction in life expectancy of 5.5 years. The degree of air pollution exceeded in China and most of the world, yet assessments of total health effects must also include other fossil fuel caused by air and water pollutants (Hansen et al., 2013).

The ecological impact of fossil fuel mining increases as the largest, easiest to access; resources are depleted (Davidson & Andrews, 2013). A constant fossil fuel production rate requires increasing energy input, but also use of more land, water, and diluents, with the production of more waste (Murphy & Hall, 2011).

Although mined areas are supposed to be reclaimed, as in the case of mountain-top removal, there is no expectation that the ecological value of reclaimed areas will be equivalent to predevelopment condition (Allen et al., 2011). Landscape changes due to tar sands mining and reclamation cause a large loss of peatland and stored carbon, while also significantly reducing carbon sequestration potential (Rooney et al., 2011). Lake sediment cores document increased chemical pollution of ecosystems during the past several decades traceable to tar sands development (Kurek et al., 2013) and snow and water samples indicate that recent levels of numerous pollutants exceeded local and national criteria for protection of aquatic organisms (Kelly et al., 2010).

Global warming of 2ºC or more would bring deleterious climate impacts. A large fraction of the injected water returns to the surface as wastewater containing high concentrations of heavy metals, oils, greases and soluble organic compounds. Carbon releases take place more in Organization for Economic Co-operation and Development (OECD) economies, though developing countries are experiencing rapid growth recently, and so, increases in carbon dioxide (CO_2) emissions. Uses of the fuel mix as well as a reduction in energy intensity in Canada have helped reduce the carbon intensity of the economy and lower emissions of conventional air pollutants from the energy sector.

RECOMMENDATION AND CONCLUDING REMARKS

Climate change is an inevitable global phenomenon that requires concerted actions by the government, business leaders and civil society to work together for human welfare, economic growth, and security. Consensus is growing on global, regional, and country targets to limit the carbon emissions to prevent catastrophic effects on human health and environment. Both the developing and the developed economies need to reduce their CO_2 intensity significantly for stabilizing the earth's climate at no more than a 2°C temperature rise.

Many ecosystems are at risk with larger climate change effects. Therefore, climate stabilization requires long-term energy balance of the planet. In light of the 2°C goal, it is essential that all countries provide fair and ambitious contributions in reducing emissions (UNFCC, 2014). Temperature increase should be limited to 1.5º C on the premise of the pre-industry level by 2020; meanwhile, the accumulative emission should reach the peak value according to the United Nations Framework Convention on Climate Change's 21st Conference of the Parties (COP21).

Impacts of carbon emission are inevitable and there is a long debate as to who bear the losses incurred due to the carbon emission. Popular view is that the industrialist countries would pay to the developing countries for the loss and damages because of the carbon emission. Decision on financing should be guided by the vulnerability of affected countries and a moral obligation to help developing countries, rather than by attribution (Hulme, 2014). The global society might further pursue efforts to limit temperature increase to below 1.5°C, which would require more significant mitigations worldwide. At the global scope, there is currently a large gap between emissions resulting from the INDCs and the least-cost levels needed for achieving the Paris Agreement goals (Rogeli et al., 2016).

Public reaction to increasingly bad air quality in developing regions (The Economist, 2013) may lead to future aerosol reductions, at least on a regional basis. Increase of Earth's energy imbalance from reduction of particulate air pollution, which is needed for the sake of human health, can be minimized via an emphasis on reducing absorbing black soot (Hansen et al. 2000), but the potential to constrain the net increase of climate forcing by focusing on black soot is limited (Bond et al., 2013).

Management of wastewater is a major technical challenge (Gregory et al., 2011). Methane leaks increase the climate impact of shale gas, but whether the leaks are sufficient to significantly alter the climate forcing by total natural gas development is uncertain (O'Sullivan & Paltsev, 2012). Overall, environmental and ecological threats posed by unconventional gas extraction are uncertain, groundwater pollution on both local and river basin scales is a major concern (Allen et al., 2011).

Carbon in the fuels is embodied in the final products and is only released at the end of the lifecycle of the product. Around 40% of global CO_2 emissions arise from industrial processes; either directly as a fuel or indirectly through emissions from the generation of electricity or refining of crude oil (Brown et al., 2012). Currently, indirect CO_2 emissions make up around 32% of total industrial CO_2 emissions (IEA, 2010). Indirect CO_2 emissions can be addressed by the de-carbonization of the electricity sector. Improved efficiency of refrigerators, fans, compressors and pumps can reduce the demand of electricity. Again, electricity can be used for production processes to reduce consumption of fossil fuels in the industry.

International "decarbonization regime" can play an important role in the mitigation efforts. However, low-carbon production technologies and less traditional use of fossil fuels requires dramatic changes in strategic planning, technological innovations, environmental regulation, low-carbon energy production technologies, relevant transport standards and infrastructure, household behavioral changes and, certainly, strong political will. Long-term cooperation frameworks need to be provided in the new climate change agreement with active participation of all major-emitting countries, as well as other international agreements under the UN, WTO, and others. However, establishment of the information basis for emission management, development and introduction of the GHG emission regulation system, strengthening the de-carbonization efforts can generate aspiring outcome for the times to come. It is also essential to undertake measures for the development of adaptation and mitigation policies for forestry and agriculture in respect of carbon sequestration capacities. Energy sector reform is important for sustainable energy development and includes reviewing and reforming subsidies, establishing credible regulatory frameworks, developing policy environments through regulatory interventions, and creating market-based approaches such as emissions trading. It is predicted that that global energy supply will continue to grow and in the types of energy likely to be used by 2030. Effective policies supporting energy supply technology development and deployment are crucial for low-carbon emission systems. Policies relating to development and deployment of low-carbon emitting technologies have been successful.

Supply of secure, equitable, affordable and sustainable energy is vital for prosperity and development. Global energy supply will continue to be dominated by fossil fuels for several decades. To reduce the resultant GHG emissions will require a transition to zero and low-carbon technologies. However, more rapid deployment of zero- and low-carbon technologies will require policy intervention with respect to the complex and interrelated issues of security of energy supply; removal of structural advantages for fossil fuels; minimizing related environmental impacts, and achieving the goals for sustainable development.

Energy services are fundamental for sustainable development. Energy supply system should introduce clean energy, improved energy security and promote environmental protection at local, regional and global levels. Sustainable energy systems emerging as a result of government, business and private interactions should be based taking consideration of both GHG mitigation potential as well as their incidental benefits. Adequate, affordable and reliable energy services have been insufficient to reduce poverty and improve standards of living in many countries. Major investments in energy-supply chain can cater conversion technologies, infrastructure, and environmental sustainability. Carbon dioxide Capture and Storage (CCS) technologies should be widely used for sustainable environment and sustainable living for the sake of humans and their planet. Rapid implementation and market competition may not ensure reduced GHG emissions. New energy supply systems with reduced carbon intensity need to be managed to minimize economic, social and technological risks. Overall, reducing emissions from industry requires a sustained and focused effort. Industrial sector is made up of different processes and manufacturing of products. Education, technical training and public awareness are essential complements to GHG mitigation policies.

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ENDNOTE

[1] IEA study of 19 countries – Austria, Australia, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Italy, Japan, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, the United Kingdom and the United States.

Chapter 5
Biological Conservation:
Can We Break the Inertia?

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ABSTRACT

Despite building a clear and compelling message about the importance of conserving biodiversity and what we risk in depleting it, meaningful engagement from implicated stakeholders remains limited. Past studies have examined the gap between the possession of environmental knowledge and displaying behavior that would help to conserve it. Essentially, increasing awareness and interest in environmental issues does not ensure that individuals will make the necessary changes in behaviours detrimental to biological conservation. This is a concern as failure to meaningfully engage the public into acting on conservation strategies will hamper efforts to curb biodiversity loss. Herein the authors investigate why action to address biodiversity loss has been slow or deficient in many jurisdictions. The authors draw from models and theories developed in health and social sciences to provide context to the key factors that prevent action and propose steps that could be taken to stimulate it.

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INTRODUCTION

Biodiversity confers protection against ecosystem instability and loss of functioning (Naeem et al. 1995; Worm et al., 2006; Cardinale et al., 2012) by providing services such as soil formation, erosion control, nutrient and hydrological cycling, and carbon storage (Daily,1997; Rands et al., 2010; Ten Brink et al., 2016; Hungate et al., 2017). Moreover, research has shown that economic value can be derived from retaining landscape features that promote biological diversity (Costanza et al., 1997; Balmford et al., 2002; Dee et al., 2017). Modern agriculture, horticulture, ecotourism, cosmetics, and pharmaceuticals, for example, are industries that draw direct economic benefits from products and/or services derived from biodiversity. Policies have thus been enacted in many jurisdictions around the world that recognise its wide-ranging importance (de Klemm & Shine, 1993; McBeath & McBeath, 2006; Miller, 2006; Mukul, 2007; Talaat, Tahir, Rusli, & Husain, 2013). Recognition at the global scale is also evident, as preventing biodiversity loss is a key tenet of the Convention on Biological Diversity (2010) and is a United Nations Sustainable Development Goal (UN, 2015). Yet despite the clear benefits that maintaining biodiversity confers, global biodiversity is still declining (Rands et al., 2010; Cardinale et al., 2012; Ceballos et al., 2015). More disconcerting is that policies and strategies adapted to conserve it are often ignored (Chunmei & Zhaolan 2010; Santamaria & Méndez, 2012; Drake & Just, 2016; Laitos, 2017), even with the pervasiveness of education materials, outreach programs, and media campaigns.

The Issue

The unique feature of the planet Earth is its biosphere. It comprises all terrestrial, aquatic and atmospheric components of earth that contain life. The relationships between its biotic and abiotic components are so intricate and complex that we are still only beginning to explain how the many ecosystems contained within function and interact. The variety of living organisms within the biosphere, the biodiversity, is the foundation for the goods and ecosystem services to which human beings are meticulously linked. As described by the Millennium Ecosystem Assessment (2005), biodiversity is "the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and ecosystems". This definition puts all biota into a holistic context through various taxonomic, genetic, and ecological relationships and links. Thus, one needs to consider the multidimensional facets of biodiversity when explaining its critical role in providing goods and services and maintaining ecosystem functioning.

Moreover, biodiversity is the key feature of the biosphere that is constantly being impacted by human activity.

Earth has about 9 million types of living organisms including plants, animals, fungi, and protists (Cardinale et al., 2012) in addition to the 7.67 billion (and growing) human beings residing alongside them (Worldometers.info 2018). Unfortunately, the ever-increasing needs of human populations have resulted in the elimination of many of these living and non-living components at an alarming rate. The escalation of species loss and the concomitant services they provide are bound have profound negative impacts on the biosphere. For example, the loss of biodiversity slows or inhibits the establishment of new habitats (Jones, Lawton, & Shachak, 1994), alters biogeochemical cycles (Sterner & Elser, 2002), and reduces ecosystem productivity (Power et al., 1996; Tilman, Reich, & Isbell, 2012). Associated research over the last several decades on the relationships between biodiversity and ecosystem functioning (more than 4000 since 2006) has helped to resolve several intellectual controversies pertaining to the importance of maintaining biodiversity (Hooper et al., 2005; Cardinale et al., 2011; Roger, 2017). There is now consensus among researchers on how loss of biodiversity impacts ecosystem functioning, the major conclusions being:

1. Biodiversity loss reduces the efficiency of biological communities to assimilate and recycle essential nutrients and produce biomass,
2. Biodiversity loss reduces ecosystem stability and functioning over time,

Box 1. Current rates of biodiversity loss

The current rate of species loss is alarming. Global species diversity is declining at rates well above background extinction levels, similar or greater to that observed during the five previous mass extinction periods (Barnosky et al. 2011; De Vos et al. 2014; Ceballos et al. 2015). Losses are observed across spatial scales, and in all major groups of flora and fauna. Projections suggest that the mean number of threatened species per country will increase 7 and 14 % by 2020 and 2050, respectively (McKee, Sciulli, Fooce, & Waite 2004). The main drivers of species extinction are anthropocentrically driven, namely habitat loss and degradation, over-exploitation, climate change, and invasive species (Sala et al. 2000; Baillie, Hilton-Taylor, Stuart, & Commission 2004; McKee, Sciulli, Fooce, & Waite 2004, He et al. 2018). Current estimates suggest that 27-33 % plant species are threatened world-wide (Pimm and Joppa, 2015). Myers et al. (2000) identified 25 hotspots across the globe that contain approximately 44 % of global plant species, with most of these hotspots being tropical rainforests. Many of the species contained within are also on the verge of extinction because of deforestation, and at current rates, extinctions could be as high as 50 000 per million species per decade by 2060 (Pimm & Raven 2000). Worldwide, 12 % of bird species are listed as threatened (Baillie et al. 2004; McKee et al. 2004) while 32 % of amphibians, 42 % of reptiles, and 23 % of mammals are also red-listed (Baillie et al. 2004). Aquatic organisms are also declining at alarming rates. Background extinction levels for marine fishes were noted as 0.1 to 1 extinctions per million species per year. Current extinction rate estimates range between 100 to 1000 times background levels (Mace et al. 2005; Rockström et al. 2009). Much of the decline is caused by overexploitation and anthropogenically driven climate change (Novacek & Cleland 2001; Atkinson et al. 2004; Xenopoulos et al. 2005; Worm et al. 2006).
Exotic species are confounding the issue. At local scales biodiversity may actually be increasing due to an influx of exotic species (Sala et al. 2000; Sax & Gaines 2003). At regional and global levels, however, biodiversity is clearly declining (Sax & Gaines 2003; Vellend et al. 2013).

3. Impacts of biodiversity loss on single ecosystem processes are nonlinear and saturating, in a way that loss in biodiversity accelerates ecosystem change,
4. Biodiversity loss has more impact on ecosystem functions across trophic levels than within a trophic level, and
5. Impacts of biodiversity loss on ecological processes can be similar in magnitude to other global drivers of environmental change.

Despite our understanding of the importance of maintaining biodiversity and the potential hardships associated with its decline, few individuals take actions that could help to prevent or avoid unwanted change. Rather, a reactive approach that responds to threats after undesirable changes in an ecosystem arise tends to be utilised when often, using a proactive approach that retains critical natural features and processes is more cost-effective (Dreschsler, Eppink, & Wätzold, 2011; Walls, 2018).

The purpose of this chapter is to examine why action to address biodiversity loss has been deficient or slow in many jurisdictions. Drawing on models and theories developed in health and social sciences that help to explain behaviour and behavioural changes, the authors outline key factors that prevent positive action and propose steps that could be taken to stimulate it. Specifically, the authors wish to:

1. Examine the utility of well-established behaviour models and theories (Health Belief Model; Theory of Planned Behaviour; Transtheoretical Model (Stages of Change)) to help explain the gap between the possession of environmental knowledge and displaying behaviour that curbs or limits biodiversity loss; i.e., determine the principle motives that initiate desired behaviours after knowledge acquisition
2. Outline the key factors preventing initiation of behaviours that promote biological conservation
3. Suggest pathways towards changing behaviours and/or encouraging the adoption of new behaviours that can lead to biological conservation

BACKGROUND

Why Should We Care?

Humans are a part of nature. As stewards of our planet we have an ethical and moral responsibility to protect and conserve biodiversity. Moreover, natural systems clearly provide us with vital economic services (Díaz, Fargione, Chapin III, & Tilman, 2006; Cardinale et al., 2012). Conserving biodiversity contained within natural systems is thus critical to our well-being. Beyond the utilitarian reasons that we recognize, there are many more services that biodiversity provides that we still do not yet fully understand or appreciate. Thus, loss of species that provide those services may be problematic if redundancy is not present in the system (Reyes & Kneeshaw, 2014). Biodiversity is also central to our well-being in other, non-utilitarian ways. In many societies nature is an integral component of cultural practices and beliefs, providing us with benefits ranging from cognitive, psychological, and physiological, to spiritual and social (Costanza et al, 1997; Kondo, Fluehr, McKeon, & Branas, 2018). Even in urban centres where links between culture and nature are becoming more abstract, people still maintain some intrinsic connection with nature, witnessed by many seeking parks and green spaces for relaxation, exercise, or engaging in social activities (Sadeghian & Vardanyan, 2013; ten Brink et al., 2016; Paul & Nagendra, 2017).

We often take these benefits for granted and do little to ensure their sustenance. Despite the overwhelming evidence for otherwise, many assume that biodiversity will always exist to provide the goods and services that we need. Why is this the case? i.e., why is there a discrepancy between knowledge and one's behaviour? Why has there been resistance to change behaviours that lead to biodiversity loss? Why do we seldom adopt proactive strategies that are potentially far more cost-effective than reactive approaches?

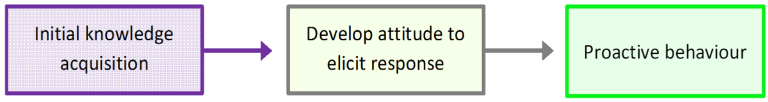
SOME MODELS AND THEORIES

Successful conservation strategies require understanding of human behaviours and the context with which they occur. Behaviour models and theories can help us to understand specific actions (or lack of) by identifying the main underlying factors that influence them. The goal here is to determine the key factors that explain behavioural responses after knowledge acquisition, with the hope that this can help develop more effective policy and intervention strategies that stimulate proactive sustainable behaviours. The following are frequently cited health and social science behavioural models and theories that help to explain behaviours after initial knowledge acquisition of a problem or issue.

Information Deficit Model (IDM)

Early behaviour models are linear in nature, suggesting that educating the public about an important issue inevitably results in desired behaviours to address it (Schahn & Holzer, 1990; Evans & Durant, 1995) (Figure 1). These are collectively known as Information Deficit Models (IDM) (Kollmuss & Agyeman, 2002). IDMs are now widely panned as more and more evidence shows that information alone rarely elicits desired behaviors (Wynne 1991; Howell 2014; Kelly & Barker, 2016; Simis,

Figure 1. The Information Deficit Model (IDM) (adapted from Kollmuss & Agyeman 2002)



Madden, Cacciatore, & Yeo, 2016). Despite this, many government institution and non-government organisation (NGO) communication campaigns are still based on the assumption that knowledge transfer results in evoking desired behavioural responses in the public. While some of these campaigns have been effective, the majority do not result in positive behavioural changes (Ziman, 1991; Evans & Durant, 1995; Bulkeley, 2000; McDivitt, 2016). Clearly, alternative approaches are needed that better resonate with society. Other models and theories have since been developed that account for the behavioural disconnect and are explained below.

The Health Belief Model (HBM)

The Health Belief Model (HBM) was developed in the 1950s to help understand why people did or did not use preventive public health services (Hochbaum 1958). It has since evolved to address a broad spectrum of health-related concerns in many different populations (Orbell, Crombie, & Johnston, 1995; Vazini & Barati, 2014; Tarkang & Zotor, 2015). The original premise of the model was that a person's beliefs about one's risk for a disease or health problem, and one's perceptions of the benefits of taking action to avoid it, influence one's willingness to respond (Hochbaum, 1958; Rosenstock, 1974; Becker & Maiman, 1975). Its current iteration generally includes five main constructs (Rosenstock, Strecher, & Becker, 1988):

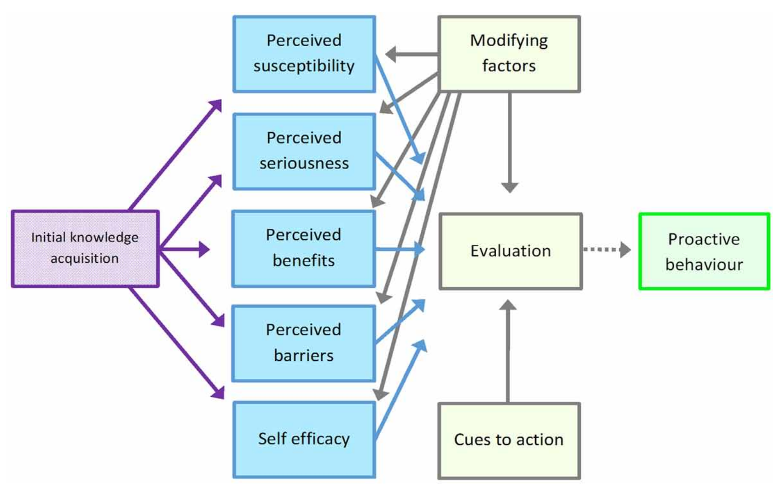
1. ***Perceived Susceptibility*** – one's assessment of chances of getting illness/ disease,
2. ***Perceived Seriousness*** – one's judgement of severity of illness/disease,
3. ***Perceived Benefits*** – one's assessment of whether adopting a new behaviour is better than status quo,
4. ***Perceived Barriers*** – one's assessment of factors that will prevent adoption of new behaviour, and
5. ***Self-Efficacy*** – one's confidence in ability to adopt behaviour (to act), along with two additional constructs:
    a. ***Modifying Factors*** and
    b. ***Cues to Action***.

Modifying factors are variables that can affect compliance depending on one's circumstances. They can include: age, sex, personality, culture, socio-economic status, interactions with health professionals, personal relationships, past experiences, incentives (e.g., rewards/prizes, recognition, financial penalties, etc.), media, and education level. Cues to action are events, people, or objects that can prompt or motivate people to change their behaviours. Personal illness (symptoms) or that of a family member, advice from friends or colleagues, institution reports, mass media campaigns, and product warning labels are a few examples. Evaluation of the advantages and drawbacks of the main constructs while accounting for the modifying factors and cues determine one's compliance with recommended actions (Figure 2).

Some of the main criticisms of HBM include: (i) inability to adequately account for social norms, (ii) lack of standardised guidelines on weighting of combinations of constructs and/or quantifying interactions between individual constructs, and (iii) its generally low predictive power (R^2 often below 21%) (Winfield & Whaley, 2002; Carpenter, 2010; Orji, Vassileva, & Mandryk, 2012); although this has not always been the case as some authors found HBMs to be strong predictors of behavioural intentions ($R^2 = 29$ to 43%) depending on study context (e.g., Bakker, Buunk, Siero, & van den Eijnden, 1997; Nejad, Wertheim, & Greenwood, 2005).

The HBM can be parameterised to address biodiversity conservation issues. The HBM provides the foundation for procedures that spur pro-environmental behaviour on issues ranging from sustainable water resource use to conserving forest cover (Goldstein, Cialdini, & Griskevicius, 2008; Chen, Lupi, He, & Liu, 2009; Morowatisharifabad, Momayyezi, & Ghaneian 2012; Straub & Leahy, 2014).

Figure 2. The Health Belief Model (adapted from Janz & Becker 1984; Abraham & Sheeran 2015)



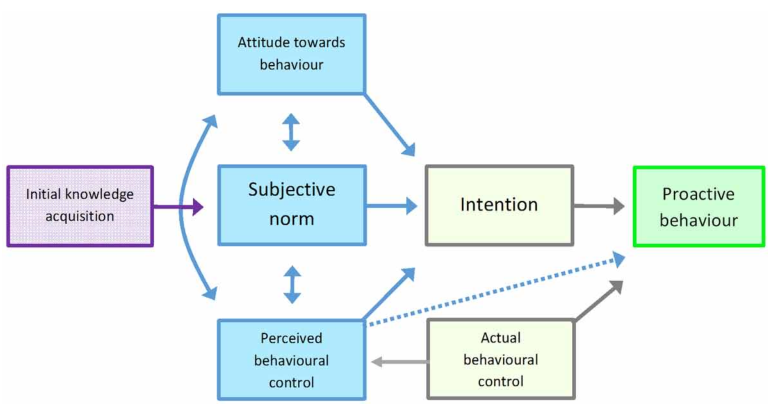
Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB) is an approach that developed as an extension to the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975; Ajzen & Madden, 1986). Much like TRA, TPB postulates that performing an action or behaviour is governed by an individual's behavioural *intention* – one's readiness and/or motivation level to perform the behaviour, and that behavioral intention can also be shaped by: (i) personal *attitude* towards the behaviour, and (ii) *subjective norms* - one's perception of whether the action will be praised or criticised by people of significance to the individual (Ajzen & Madden, 1986). The key construct added to the TRA model is the inclusion of (iii) *perceived behavioural control* (Figure 3).

Perceived behavioural control is defined as the perceived ease or difficulty in successfully performing a behavior (Ajzen 1991), and is likened to the self-efficacy construct in the HBM. The addition of the perceived behavioural control construct has made TPB a much better predictive tool than TRA, and is thus more widely utilised. The extent that perceived behavioural control directly influences action is also thought to depend on actual behavioural control – a construct added to the original model defined as the extent or degree to which an individual has the abilities, capacities, skills, and other requirements needed to perform the behavior in question (Ajzen, 2015). The TPB model has been used to explain a considerable portion of observed sample variance in many studies (e.g., 14 to 66% in the studies cited here: Godin & Kok, 1996; McEachan, Conner, Taylor, & Lawton, 2011; Hadadgar et al., 2016).

Some of the main criticisms and concerns associated with the TPB include the following: (i) the scaling method used to define each belief-based construct can affect the correlation coefficients between indirect and direct measures, and

Figure 3. The Theory of Planned Behaviour (adapted from Ajzen and Madden 1986; Ajzen 2015)



thus, interpretation of results (Gagné & Godin, 2000), (ii) no true account for the distinction between perceived *versus* actual behavioural control is made, although some modified versions of TPB have since quantified actual behavioural control as a distinct construct (Sheeran, Trafimow, & Armitage, 2003; Ajzen 2015), (iii) the TPB model does not account for affective variables such as emotions, feelings, or drives that can substantially influence behaviour (French et al., 2005), and (iv) some authors contend that TPB is linear and static in nature and cannot account for changes in behaviour over time (Sniehotta, Presseau & Araújo-Soares, 2014). Note that Ajzen (2015b) himself has disputed this claim.

The TPB has since been adapted to predict or explain a wide range of biological conservation-related behaviours including promoting biodiversity in agricultural communities, adopting sustainable agricultural practices, green purchasing behaviour, and willingness to pay for environmental services, among others (Liebe, Preisendörfer, & Meyerhoff, 2011; Meijer, Catacutan, Sileshi, & Nieuwenhuis, 2015; Menozzi, Fioravanzi, & Donati, 2015; Liobikienė, Mandravickaitė, & Bernatonienė, 2016).

The Transtheoretical Model/Stages of Change (TTM)

The Transtheoretical Model (TTM) integrates key principles and constructs of change from other leading theories of behavioural change (Prochaska & Di Clemente, 1982). This was done to combine the salient ideas from a growing number of psychotherapy theories into a single, comprehensive theory of change that is applicable to a wide variety of behaviours in different contexts, populations, and environmental conditions (Prochaska & Velicer, 1997). In essence, TTM describes the process of how individuals intentionally modify problematic behaviours and/or adopt beneficial ones. The TTM consists of five core constructs: (i) *Stages of Change*, (ii) *Processes of Change*, (iii) *Decisional Balance*, (iv) *Self Efficacy*, and (v) *Temptation*.

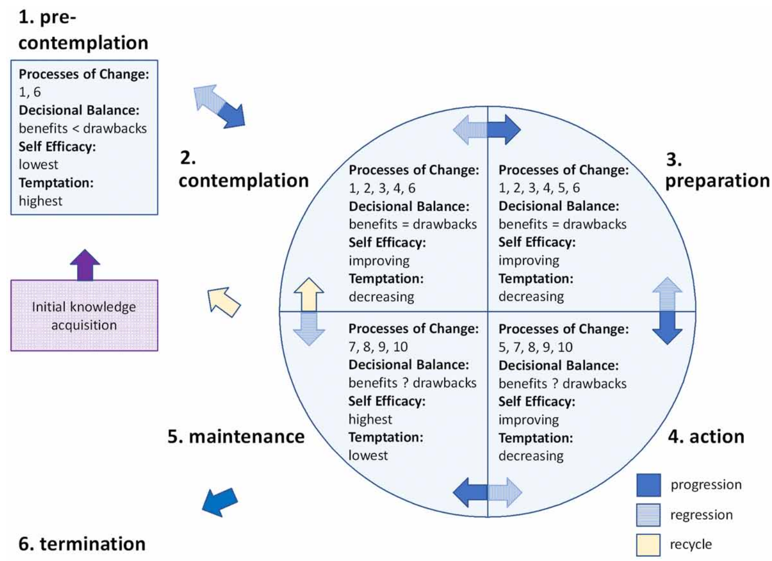
Central to the model are the six Stages of Change, a temporal construct that acknowledges that positive intentional behavioural change is a process that manifests over time. It involves progression through a series of stages that can occur in a linear or cyclical manner, given that individuals can advance or regress to earlier stages depending on the influence of the other core constructs (Figure 4). The rationale for establishing distinct stages is that individuals at a particular stage would face similar challenges and barriers, and could thus be aided using similar approaches. The Processes of Change are behavioural activities that facilitate change across stages. These activities can either be publicly displayed or are private in nature. Ten Processes of Change are currently recognised:

1. ***Consciousness-Raising:*** *Increased knowledge about behavioural problem/issue*
2. ***Dramatic Relief:*** *Increased awareness of feelings and emotions towards problem/issue*
3. ***Self-Re-Evaluation:*** *Determine an image of oneself with and without problem/issue*
4. ***Environmental Re-Evaluation:*** *Awareness of impact of problem/issue on others &/or physical environment*
5. ***Self-Liberation:*** *One's belief and commitment to changing behaviour to address problem/issue*
6. ***Social Liberation:*** *Awareness of public support through advocacy, empowerment, social programs, policy interventions, etc.*
7. ***Counter Conditioning:*** *Knowledge of alternate or substitute behaviours to replace problem/issue*
8. ***Stimulus Control:*** *Manage one's environment to remove cues for behavioural problem/issue and add prompts that encourage beneficial one(s)*
9. ***Contingency Management:*** *Use rewards and/or punishment to reinforce beneficial behaviour*
10. ***Helping Relationships:*** *Obtain public support via self-help groups, counselling, etc. (Prochaska & Velicer 1997)*

The relative importance of a process may be dependent on the Stage of Change, with cognitive and affective processes such as Consciousness-Raising and Dramatic Relief being more important earlier while behavioural processes such as Stimulus Control and Contingency Management appear to be more important at later stages (Figure 4). Transition between stages is also impacted by Decisional Balance, Self Efficacy, and Temptation. Decisional Balance refers to evaluating the benefits and drawbacks of making the behavioural change. The key ideas for this construct were adapted from Janis & Mann (1977). Self Efficacy is as explained for the HBM above, and Temptation, the assessment of how inclined or prone one is to engage in a problem behaviour in particular situations (Prochaska & Velicer, 1997), is the last of the core constructs.

The TTM has been used to explain a considerable portion of observed sample variance in many studies (e.g., 8 to 43% in the studies cited here: Van Duyn et al., 1998; Maddison & Prapavessis, 2006; Gazabon, Morokoff, Harlow, Ward, & Quina, 2007; Dishman, Vandenberg, Motl, & Nigg, 2010). Some of the limitations and criticisms towards the TTM include the following: (i) the Stages of Change construct is an oversimplification of the behaviour change process that imposes artificial categories on a continuous process, (ii) a universally accepted standard of how to determine an individual's current stage of change is unavailable, (iii) it

Figure 4. The Transtheoretical Model of Change (TTM) showing all five core constructs: Stages of Change, Processes of Change, Decisional Balance, Self-Efficacy, and Temptation (adapted from Prochaska & Di Clemente 1982; Dishman, Vandenberg, Motl, & Nigg 2010). See text for descriptions of the ten Processes of Change.



is unclear how much time is needed before progressing to another stage, (iv) the TTM assumes that individuals make coherent and rational judgements during the decision-making process when this is not always the case, (v) the TTM does not account for the social and environmental context (e.g., socio-economic status, income) in which the behaviour change occurs, and (vi) applying the model to complex behaviours is difficult; e.g., physical activity and dieting, and can result in erroneous self-assessment of one's performance and accomplishments (Bandura, 1977; Etter & Perneger, 1999; Marshall & Biddle, 2001; Sutton, 2001; Littell & Girvin, 2002; Adams & White, 2004; Bridle et al., 2005; West, 2005).

The model has primarily been used to assess health-related behaviours but has more recently been applied to foster behaviours that promote biological conservation (Dierking et al., 2004; Shaw, Radler, & Haack, 2011; Moss, Jensen, & Gusset, 2016; Mouro & Castro, 2017).

SOLUTIONS AND RECOMMENDATIONS

Can These Theory-Based Strategies Help With Biological Conservation?

Behaviour models and theories are increasingly being used to address problems and issues outside the purview of health and social sciences. Similar challenges are encountered in terms of determining the relative importance of key constructs and modifying factors that predict the initiation of desired action, how these variables relate and/or interact, how models and theories translate in different populations, contexts, and situations, and if the chosen model or theory can be parameterised to address a range of different problems or issues. Moreover, determining the level of precision needed to make reliable predictions is also proving difficult. Integrating too few constructs and/or modifying factors and the resulting model or theory explains little of the population variance under study while too many can not only make information unwieldly to gather and analyse, but also produce results that are less generalisable.

Ultimately, the value of a model or theory can be assessed according to its reliability in predicting behaviour in a systematic manner while using a manageable number of constructs and modifying factors. Given that each of the above models and theories are best suited for different issues, contexts, situations, and levels of organisation in function of both time and space, taking useful elements from each rather than trying to fit biological conservation into a particular model or theory's framework will best suit the authors' purposes here.

Moving Forward: Interventions to Change Behaviour

Each of the models and theories have common and unique elements that are useful when planning behavioural interventions. Self efficacy, for example, is common to the Health Belief Model (HBM) and Transtheoretical Model (TTM). Perceived Susceptibility and Perceived Seriousness are unique to the HBM, while some processes of change such as Social Liberation are only utilised in the TTM. Note also that some of the similar constructs between models and theories are described using different terminology. For example, Normative Beliefs and Activities are described as Cues to Action in the HBM, Subjective Norms in the Theory of Planned Behaviour (TPB), and is a Process of Change in the TTM, while Self Efficacy in the HBM and TTM is synonymous with Perceived Behavioural Control in TPB (nb., please see Noar & Zimmerman, 2005 for more in-depth comparisons).

All models and theories presented here provide valuable information for developing effective behaviour interventions that promote biological conservation. The key messages that can be extracted from the models and theories include:

1. **Knowledge:** Knowledge alone rarely spurs desired action (Wynne 1991; Blake 1999). Other intrinsic and extrinsic factors such as intention, evaluation of cost-benefits, societal norms, and one's attitude towards performing the behaviour can influence responses to knowledge acquisition.
2. **Intention:** Intention to perform a behaviour can be a good predictor of desired positive action. Intention, however, can be influenced by other constructs and modifiers and thus, does not always lead to desired behavioural changes (Sutton, 1998; Waylen, McGowan, Pawi Study Group, & Milner-Gulland, 2009).
3. **Perceived Efficacy:** The belief in one's capacity to make a difference is important. Reasonable expectations or benchmarks should be set when designing interventions as expectations can influence perceived efficacy, and thus, intention to act.
4. **Actual Behavioural Control:** Having the abilities, capacities, skills, and other requirements to perform a desired action is critical to successful intervention.
5. **Normative Beliefs:** Normative beliefs can be significant drivers of desired action as one's personal belief system and other community member's attitudes and behaviours towards the action can strongly influence one's commitment to act (Bandura 1977; Goldstein, Cialdini, & Griskevicius 2008).
6. **Context:** The effectiveness of a model or theory is context-specific. Models used for the behaviour under study should be periodically re-evaluated at appropriate spatio-temporal scales given that individuals, communities, and socio-ecological contexts can change over time.
7. **Barriers:** Other psychological and contextual barriers can deter an individual from committing to action even if one is inspired to do so. Social context, for example, can spur or negate action depending on how strongly one identifies with the reference community (Kollmus & Agyeman, 2002; Griskevicius, Cantú, & van Vugt, 2012; Lindemann-Matthies, Keller, Li, & Schmid, 2014).

In reference to (7), barriers can also impact the relative importance of the key constructs included in behavioural intervention models. Thus, barriers need to be closely scrutinised when developing intervention strategies given their ability to significantly inhibit or modify expected behavioural responses. Some commonly cited psychological and contextual barriers that can impact the expression of desired behavioural action are described here:

Uncertainty with how and why biodiversity conservation is important to one's well-being; i.e., how does conservation directly benefit the individual? While maintaining biodiversity has recently been linked with the stability of intrinsic, cultural, and utilitarian ecosystem services (Cardinale et al., 2012), many of the benefits are difficult to perceive at the individual and even local community level on a day-to-day basis. Moreover, how biodiversity is fundamental to one's mental and physical health is less clear and difficult to quantify (Clark et al., 2014).

Lack of clarity in terms of what exactly needs to be conserved. Should we try to conserve all components of biodiversity across the landscape or only those that we deem necessary to maintain ecosystem functioning and stability? Can we accurately quantify how much biodiversity needs to be sustained to maintain the provisions and services that biodiversity currently provides? How do we weigh the relative importance of intrinsic, cultural, and more utilitarian benefits in our assessments? Is the lack of a universally-accepted standard approach to define and quantify biodiversity hindering our conservation efforts? While efforts to address these questions are ongoing (e.g., Balmford et al., 2002; Thompson & Starzomski, 2007; Balvanera et al., 2014; Capmourteres & Anand, 2016; Dee, De Lara, Costello, & Gaines, 2017), they remain unresolved for many jurisdictions and are thus hampering efforts to provide a clear, consistent message and approach.

Reduced opportunities to interact with natural systems. The proportion of citizens residing in urban areas is increasing worldwide (UN 2014). The absence of contact with nature/biodiversity may contribute towards a lack of interest and involvement in conservation programs (Miller, 2005; Pergams & Zaradic, 2006; Peen, Schoevers, Beekman, & Dekker, 2010).

Weak or inappropriate government institution environmental policies and regulations. The non-binding nature of many policies makes them difficult to enforce – greatly reducing one's need or willingness to comply. However, development and public acceptance of more stringent legislation can also be problematic because of social preferences, perceived economic ramifications, and unfavourable changes to property owner rights, among other issues. Government-sponsored conservation interventions, for example, were shown to erode social norms or taboos that historically provided informal protection for certain Screw Pines (*Pandanus spp*.) used by local communities in Fianarantsoa, Madagascar (Jones, Andriamarovololona, & Hockley, 2008). Because ownership of the resource was formally transferred to a National Park, care was no longer taken to ensure the plant remained viable when harvesting its biomass. Moreover, the lack of transparency with respect to policy development and decision making has led to mistrust towards government institutions in some jurisdictions (Dalton, 2005; Chen, 2017), further fueling resistance to comply with environmental legislation.

Economic considerations. For many individuals, it is not clear if pro-environmental behaviour is economically beneficial or detrimental. This uncertainty can result in resistance to behavioural change interventions. Even when the economic advantages of co-opting behaviours that help with biological conservation are clear, many are still unwilling to adopt them (Thøgersen & Crompton, 2009), particularly if the burden on personal freedoms and changes to lifestyles are high. This indicates that financial considerations alone are not good predictors of positive action. Economic costs of compliance, for example, may be weighted against non-fiscal benefits such as direct impact on one's health, access to cleaner air, or even against time management and convenience.

Inappropriate media coverage of the environment. Although media coverage has increased in recent years, information is often distorted by magnifying the alarming aspects of an environmental issue to attract public attention (Shanahan, 2008). Moreover, inherent links between environmental issues are not often made, resulting in disconnect and failure to perceive issues in a broader context, or to recognise how multiple issues can interact. Some media outlets describe the science behind certain environmental issues as extremely complex, controversial, and/or disconnected from societal interests (Novacek, 2008), which has led to general apathy towards environmental problems and issues today (e.g., climate change). Further, a common tactic to communicate environmental messages is to incite fear. Fear-inducing communication approaches have been effective for modifying social and health-related behaviours (Tannenbaum et al., 2015). For environment-related issues, however, fear seems ineffective in stimulating positive engagement (O'Neill & Nicholson-Cole, 2009), and may in fact exacerbate general apathy and disinterest concerns.

FUTURE RESEARCH DIRECTIONS

We need to bridge the gap between knowledge acquisition and proactive conservation behaviours. Theoretical models can help by providing direction and focus to intervention strategies. To be of value, the model or theory needs to reliably predict behaviours in a systematic manner while being practical and cost-efficient to use. Given that the key factors initiating responses to biological conservation issues can differ and change over time in different socio-ecological, political, spatial, and other contexts, the authors believe that no single established model or theory examined here can best capture the variance in individual behavioural responses. Rather, extracting useful elements from each model or theory would be the most pragmatic approach. This avoids the limitations and constraints of trying to fit conservation behaviour data into a framework designed for other purposes. To ensure that we include all key elements in our intervention strategies and fully address the critical issues and concerns, better collaboration between social and ecological researchers, managers, and policy makers is needed. This will ensure that the most effective strategies are utilised.

Determining the factors that initiate pro-conservation behaviours is no easy task. Individuals are faced with multiple personal and societal barriers and norms that differ with context, all of which can also change over time. Nevertheless, the key constructs and elements derived from the Health Belief Model, Theory of Planned Behaviour, and Transtheoretical Model outlined here provide a foundation for developing effective intervention strategies. Fishbein et al. (2001) streamline this further by suggesting that for any desired behaviour to occur, at minimum one must have:

1. A strong commitment (positive intention) to perform the behaviour in question
2. The needed skills to perform the behaviour (actual behavioural control)
3. A social and physical environment (normative beliefs) that favours the beneficial action and/or one that minimises any constraints.

All other constructs and barriers, while potentially important, would serve to influence or modify one's intent (Fishbein et al., 2001). Either way, it is clear that changing human behaviour is critical to conserving biodiversity. To do so socio-ecological researchers, managers, and policy makers must collaborate and consider the following:

1. Critical to successful interventions will be to engrain that we are all part of nature, inherently dependent on its richness and diversity, and strongly impacted by its loss on a personal level. Delivery of this message needs to be clear, concise, and compelling. Ambiguity can lead to apathy, and ultimately, reduced intention and desire to engage in beneficial behaviours (Kollmuss & Agyeman, 2002; Juneman & Pane, 2013).
2. Understand the socio-ecological contexts and social norms of the communities into which we are attempting to introduce change before intervening. A mismatch of policies and intervention strategies with the target population may have limited impact on biodiversity conservation. We must also ensure that policies and interventions implemented at the local level are congruent with those at broader scales; i.e., while intervention strategies may differ between communities, the outcomes should be synonymous. Action is more likely if the perception is that the desired behaviour is a common societal objective.
3. Innovative mechanisms are required to broadcast this message far and wide, and to ensure that it elicits desired behavioural actions over a short timeframe.

Again, the message should be context-specific by acknowledging any differences in social norms between jurisdictions, and thus, tailoring interventions accordingly. Modern tools such as the internet, wireless technology, social media apps, webinars, video streaming, etc. should be used to quickly spread and reinforce this message. Smith, Angus, Ballantyne, & Packer (2011), Park (2013), and Howell (2014b), for example, have shown the effectiveness of websites, twitter, and videos, respectively, to influence behaviour.

4. Avoid utilising information-intensive interventions as they can result in feelings of loss of control or of being overwhelmed. Inundating your target populations with too much information can hinder pro-conservation behaviours rather than promote them.
5. Encourage alternative behaviours that are beneficial to conservation as they are more likely to induce change versus attempting to directly restrict or prevent undesirable behaviours. Moreover, desired behaviours should be straightforward to do and be supported community-wide by having the appropriate infrastructure, incentives, and advocacy/support groups in place to facilitate the desired action. Some intervention strategies that could help include: improving infrastructure that helps promote beneficial behaviours (e.g., wildlife corridors, buffer crops, urban green spaces, bike lanes, recycling bins, composting programs), marketing of certain products and services, community recognition/awards, financial incentives and compensation schemes, employment, community-based resource management, and effective policy and regulation (e.g., land-use zoning, quotas, banning plastic bags, replacing toxic substances in personal care and household products, etc.).
6. Align desired behaviours to be compatible with socio-economic interests rather than force individuals to choose between one or the other when and where possible.
7. Strive to embed biodiversity conservation into social norms. By identifying the model citizen as one that actively participates in pro-conservation behaviour it can help to normalise the concept, and thus, elicit a sustained, enduring response. To this end, having appropriate spokespeople that can influence social norms is clearly important (Preister and Petty, 2003; Wang, Cheng, & Chu, 2013; Grigaliūnaitė & Pilelienė, 2015).
8. Care must also be taken when designing interventions as spill-over effects of behaviour change can also be negative (Tiefenbeck, Staake, Roth, & Sachs, 2013; Meijers, Verlegh, Noordewier, & Smit, 2015). Thøgersen and Ölander (2003), for example, documented a negative relationship between purchasing organic food and use of public transportation while Barr, Shaw, Coles, & Prillwitz (2010) reported that individuals who generally have an environmentally-conscious

lifestyle at home are also most likely to use carbon-intensive travel methods while vacationing.

9. Effort should be made to identify the values and motivations of individuals who are not interested in carrying out desired pro-conservation behaviours. Including these factors into intervention strategies is clearly important to bridging the information acquisition to desired action gap.
10. We must be cognisant that most behaviour change is slow and incremental, and that maintaining desired behaviours generally requires both continuous engagement and periodic re-assessment of the effectiveness of the intervention approaches used. Timing of engagement events is also important, as the closer an opportunity to engage in a desired behaviour is to when the information was provided (and evaluation of intention to act was completed), the greater the likelihood that one will do so.

CONCLUSION

Changing human behaviour is critical to conserving biodiversity. Elements of the Health Belief Model, Theory of Planned Behaviour, and Transtheoretical Model can help by providing direction and focus to modern intervention strategies. To encourage people to actively pursue behaviours that foster biological conservation, we need deepen awareness of one's innate connections with nature. This link should be developed from a clear, concise, and compelling message about the importance of conserving biodiversity to one's well-being. While encouraging action at the individual level, we must create a sense that commitment is also important and impactful to one's local community and beyond. Multiple strategies that not only improve awareness and understanding of what we stand to lose, but also stimulate immediate action through rapid and effective knowledge transfer using all available platforms should be employed. Focus should also be placed on empowerment and skill development, policies that provide a unified and cohesive message at multiple jurisdiction levels, and fostering supportive, inclusive socio-ecological environments for all citizens. Moreover, setting reasonable, incremental goals and periodically reviewing the progress of each intervention strategy are critical to the long-term success of intervention programs.

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Chapter 6
Educating for a Sustainable World:
Bringing Together Indigenous and Western Knowledges

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ABSTRACT

Educating for a sustainable future and learning to live within our planetary limits is the most pressing challenge of our times. In this chapter, the authors present an emerging model of transcultural education that brings together Indigenous and western knowledges. This approach aims to engage learners from different cultures and knowledge traditions with the purpose of guiding them through ideas and processes of imagining, listening, speaking, and working together in a way that respects differences, acknowledges common ground, and seeks to co-create new knowledges. Bringing together Indigenous and Western knowledges in this manner creates a unique context that can potentially build the mindsets, skills, and dispositions that are needed for living and managing sustainably. A pedagogy grounded in this approach can potentially promote student interest and engagement across cultural and social divides, foster successful learning about bridging social inequalities, and cultivate an ethos of social, cultural, and environmental responsibility.

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INTRODUCTION

The most important task in our time is not to protect the land or create social justice but to create a sustainable culture. -Holthaus, 2008, p.6.

The world faces a cascade of challenges that grow in magnitude and complexity on a daily basis. Many voices within institutional and academic communities have drawn attention to the central role of higher education in tackling the complex challenges of ecological, economic, cultural, and social sustainability. There is a growing awareness that the current trajectory of development features unsustainable rates of consumption, waste generation, ecological destruction, greenhouse gas production, poverty, and social inequality. Countless examples of these complex issues can be found around the globe and in our own backyard. Creating a sustainable future and learning to live within our planetary limits is vital in our times. An interdisciplinary education focussing on environmentally and socially sustainable ideas and practices helps our students gain an awareness and knowledge of the importance of promoting and leading sustainable communities.

In light of these challenges, there is increased attention in both sustainability studies and management education on educating for innovative ways of advancing new ideas that promote more sustainable forms of enterprise. To date, however, only modest progress has been made by educators to better equip students to tackle complex strategic, moral and ethical dilemmas with knowledge, values, sensitivity and conviction. Fostering sustainability is a ‘wicked problem’ that-challenges us to identify and negotiate self-referential dilemmas that arise when we question and ultimately challenge the-core assumptions of our socio-economic systems. According to Audre Lourde (1984), it may be that the master’s tools may not be adequate to renovate the master’s house.

In this chapter we present an emerging model of transcultural education that acknowledges the need to engage new sets of knowledges and to bring these knowledges into conversation with each other. Following Ermine (2008), by “transcultural” we mean engaging learners from different cultures and knowledge traditions with the purpose of guiding them through ideas and processes of imagining, listening, speaking and working together in a way that respects differences, acknowledges common grounds, and seeks to cocreate new knowledges. We argue that the fundamental challenge of educating tomorrow’s leaders for a sustainable world begins by questioning the core assumptions of traditional western approaches to organizing in general, and sustainability in particular. In contrast to dominant western educational narratives, pedagogies, and curriculum developed for sustainability-related disciplines, we argue that a transcultural approach that ‘brings together’ Indigenous and western ways of knowing presents qualitatively different opportunities and challenges for successfully engaging these core issues. We further argue that bringing together Indigenous and western knowledges in a transcultural approach provides a promising and unique context that can potentially build the mindsets, knowledges, skills and dispositions necessary for living and managing sustainably in our challenging times.

We conclude with a reflection on the current challenges, future directions and implications for a pedagogy and a curriculum for a transcultural approach that brings together Indigenous and mainstream western perspectives on a more sustainable future. Change begins from within the individuals and is advanced through policies, programs, procedures and institutions.

BRINGING TOGETHER INDIGENOUS AND WESTERN KNOWLEDGES

This emerging model of transcultural education is grounded in a series of 'meaningful conversations' or dialogues that engage learners in a transcultural approach to realizing core learning objectives related to sustainable values, principles and practices. It builds on the insights of Gary Holthaus that Indigenous cultures, as a result of their longevity, have something to teach us about how to create sustainable communities and societies (Holthaus, 2007). Indigenous philosophies emphasize the importance of dialogue and meaningful conversation as a key element to the creation of new knowledge and new ways of doing things. In a similar line of inquiry, Mi'kmaq Elder Albert Marshall advanced the idea of 'two-eyed seeing' that created the possibility of an informed and critical conversation between Indigenous Knowledge and Science (Bartlett, Marshall, & Marshal 2012).

Cree Elder Willie Ermine has developed the concept of 'ethical space" (Ermine, 2007) which sets out the principles for an inter-cultural conversation and co-creation. The Haudenosaunee idea of 'The Good Mind' further contributes to the quality of mind that is needed for this conversation. Indigenous philosophies emphasize the notion of sustainability. For example, the Haudenosaunee philosophical principle expressed as 'the seven-generation rule' asks that decision makers consider the needs of those living seven generations from now. The future is conceived of as set of faces coming towards us, building our relationship with the future. As individuals, we are all bound together and have a set of responsibilities towards one another. The Anishinaabe concept of 'Bimaadiziwin[1]', and the Nguni Bantu concept of 'Ubuntu[2]' are examples of Indigenous worldviews that focus our attention on our relationships to each other that bind us together. In all these examples of worldviews grounded in Indigenous knowledges, our responsibilities are also extended to non-humans as part of the ethical ground that we work within.

It is important at the onset to clarify the meaning of 'Indigenous knowledges'. It is a term that defies simple definition. It includes ancient knowledges that have been transmitted from one generation to the next through millennia; it includes spiritual knowledges that are practiced through ceremony and everyday living; it includes land-based knowledges and empirical observations that are grounded in particular ecologies, both rural and urban; it includes the ontologies and epistemologies encoded in Indigenous languages that shape perceptions, ideas, and knowledge creation practices. Indigenous knowledges evoke our relationship with other living beings in the universe ("all our relations") and our responsibility to live in balance with all life. (Newhouse, 2008)

Revitalizing Thinking About Sustainable Societies Through Indigenous Knowledges

Gary Holthaus argues that creating sustainable societies requires the creation of a collective culture of sustainability (Holthaus, 2007). Instead of framing sustainability in traditional western terms as a notion of continuous yet 'responsible' development, he characterizes sustainability as a worldview that informs our individual and collective thinking and actions. He asserts that sustainability is more than just a state of nature or a development strategy guiding organizational actions; above all, it is grounded in a series of cultural understandings that inform a way of 'being' in the world; something that we work towards on a continuous pathway through time (Holthaus, 2007). The foundations of this culture are remarkably similar to Indigenous knowledges of traditional peoples. As Holthaus notes, " It is a story of co-operation instead of competition, of connections rather than fragments, of respect instead of condescension, of openness instead of secrecy, of good health and advantage for all instead of extravagant profit for a few" (Holthaus, 2007, p.219). The Anishinaabe use the medicine circle[3] to teach that we are all connected, that we are part of a larger social structure, that cooperation creates a greater good for all, that one respects nature rather than trying to control it and that a good life, bimaadizwin, requires a constant balancing of the physical, emotional, mental and spiritual aspects of existence. Individuals are taught that they are embedded within families, clans and nations and that they are interdependent: an individual depends upon others for their existence and the nation depends upon the individual for its existence. We are all bound together and need each other in order to survive and thrive.

According to Holthaus (Holthaus, 2007), a sustainable culture has several inter-related characteristics:

1. Acknowledges the centrality of relationships between all living things and the land. A sustainable culture, "…recognizes that all health is directly related to the health of the soil" (Holthaus, 2007, p122). The Cree concept of 'miyupimaatisiiun' or 'being alive well' links the health of human beings to the health of the environment: One cannot have a healthy society without having a healthy soil (Adelson, 1998).
2. Recognizes the relationships between humans and other creatures and seeks to create healthy relationships with all.
3. Nurtures, promotes diversity, "…takes not only of the human species but others as well…also takes care of ethnic diversity including language diversity, ceremonial and ritual diversity and diversity of worldview" (Holthaus, 2007, p.122).
4. "...is a socially and economically just culture, recognizing that wealth is never an individual or corporate accomplishment. It is a gift of society" (Holthaus, 2007, p.122). Corporations operate with a social license and have a responsibility to return a portion of what has been taken.
5. "…provides all citizens with a sense that we are all in this together. It nourishes its artistic enterprises…its academic enterprises…supports education systems for everyone" (Holthaus, 2007, p. 124).
6. "…affords its citizens avenues of meaning and…understands the implications of its stories we tell ourselves." (Holthaus, 2007, p.123).
7. "…has sustainable food sources…sustainable energy sources and …avenues of new development including intellectual growth and spiritual development not just economic growth" (Holthaus, 2007, p. 124)
8. "…revitalizes the cultural relevance and centrality of deeper, spiritual understandings to sustainability discourse: ''the soil of spirituality, the indispensable element that nourishes a healthy spirituality, lies less in religions than in language—in a culture's best stories, songs, and poems" (Holthaus, 2007, p.135).

Holthaus characterizes sustainability as, "… a world-view that recognizes the relationships, the connections that ramify through every aspect of Nature including the human and knows itself to be dependent upon the land.' (Holthaus, 2007, p.125). Sustainability is founded and operates on a set of principles, including self-cultivation and attention. Self-cultivation refers to the cultivation of the capacity for 'genuine respect for every essential aspect of every relationship in our human culture…including our connections to ecosystems, other critters, and the soil.' (Holthaus, 2007, p.127). He characterizes attention as the cultivation of 'paying attention to the world, being wholly present to it and being engaged in it in a way that all that allows all life to thrive (Holthaus, 2007, p.128). Fostering the creation of a sustainable culture as Holthaus envisions is a complex task that requires the creation of a space where an informed and critical dialogue can occur. We believe that Indigenous learning traditions with their emphasis on dialogue can be helpful in promoting these spaces. Indigenous leaders have been involved in transcultural conversations with different knowledge systems for at least half a millennium. In the following section, we describe three Indigenous concepts: Two-Eyed Seeing, Ethical Space, and the Good Mind that can be used to guide transcultural conversations.

Two-Eyed Seeing: Creating a Space for Two Sets of Knowledges

Mik'maq Elders Albert and Munera Albert, working with Cheryl Bartlett have developed the concept of 'two-eyed seeing' as a frame for bringing Indigenous and western (or mainstream) knowledge systems together. The foundation of their work was a desire to create an ethical frame that enabled Indigenous knowledge and western knowledge to learn from each other in addressing ecological and social issues within each set of communities. This frame has been adopted with great success in the critical area of Indigenous health research (Charleton, 2017; Kapyrka & Dockstator, 2012).

Two-eyed seeing is a guiding principle that can be used to bring together different perspectives: "we learn to see from one eye with the best in the Indigenous ways of knowing, and from the other eye with the best in the western ways of knowing and, moreover, we learn to use both these eyes together, for the benefit of all (Bartlett, Marshall and Marshall, 2012, p.335)". It is based upon long-established understandings and traditional practices that value multiple perspectives and collaboration. Two-eyed seeing asks us to suspend our judgement of the knowledge presented by the other, to take the time to consider what is being presented and to suspend judgement in order to understand its strengths and weaknesses. It requires collaboration, cooperation, challenge and trust as well as particular qualities of mind. It also requires a willingness to engage the other in an ethic of respect and not knowing through a difficult and often challenging process of collaborative inquiry. In addition to being an ethical guide for engaging with other knowledges, two-eyed seeing as an Indigenous concept is based upon the view that we're all in this together: humans and non-humans and that we all have responsibilities for each other. Two-eyed seeing asks us to consider not just the science of things, but the viewpoints of participants including humans, animals, water, land and air. It challenges us to find ways to include them in our dialogue.

Ethical Spaces: Ethical Principles for Learning Together

Ermine, a Cree Elder and Scholar, explores the concept of an ethical space and critically examines its relevance for transforming interactions between Indigenous and Canadian settler societies. Framing the interaction between knowledge systems as an ethical issue requires one to pay attention to the rules of interaction between them. According to Ermine (2007), ethical space is a theoretical space of engagement between two disparate societies with distinct cultures and worldviews. These societies initially interact as "two solitudes" whose existing "rules of engagement" drive them towards and 'either-or', mutually exclusive state of polarization and ongoing conflict. In contrast to this status quo, the ethical space of engagement offers a context that both acknowledges and respects these differences, while recognizing the potential for these distinct and often divergent worldviews to inform and enrich each society: "…diverse human communities do not share a common moral vocabulary, nor do they share a common vision of the nature of human beings as actors within the universe" (Ermine, 2007, p.198).

He proposes that this ethical space of engagement, driven by multiple complimentary processes, represents a context for developing, "a framework for dialogue between human communities" (Ermine, 2007, p. 193) that enable them to redirect their current patterns of engagement. In this revitalized context of engagement, Ermine sees the potential to replace the norms of knowledge domination, cultural oppression, and assimilation of Indigenous societies into western society with an ethic of equality and transculturally grounded coexistence. He notes that while Indigenous peoples and western societies are typically "divided by the void and flux of their cultural distance" (Ermine, 2007, p.194), there is an opportunity to reframe their historically embedded approaches to "encounter each other" and bring about a qualitative difference in the nature of their intercultural engagement.

Ermine proposes that this new notion of partnership can promote a collaborative and mutually respectful spirit between Indigenous peoples and western institutions, creating new directions of thinking within Canadian legal discourse that transcend the status quo of archaic ways of interaction. Ermine, Sinclair, and Jeffery (2004) emphasize that "…as a process, the fundamental requirements of the ethical space include an affirmation of its existence. The ethical space cannot exist without this affirmation. The affirmation of the space indicates that there is an acceptance of a cultural divide and a direct statement of cultural jurisdictions at play. The ethical space also requires the dialogue about intentions, values, and assumptions of the entities towards the research process" (Ermine et al. 2004, p. 21). While Ermine's substantive interest is in examining how such a framework can change interactions between Indigenous and Canadian law, his construct of ethical space offers a potential direction for addressing the challenges of a transcultural education. His notion of

Figure 1. Face to face
Shaney Komulainen, Canadian Press, 2001

ethical space is premised on the core argument that reconciling worldviews is the most effective way of guiding successful cultural encounters: "Shifting our perspectives to recognize that the Indigenous-West encounter is about thought worlds may also remind us that frameworks or paradigms are required to reconcile these solitudes" (Ermine, 2007, p 201).

In his book, Towards Deep Subjectivity, Roger Poole (1972) coined the term ethical space to describe an abstract space of possible encounter and interaction between two entities with different intentions.

Roger Poole's analogy of an ethical space as a way of bridging distance between cultural entities was inspired by a photograph taken during the Russian occupation of Czechoslovakia. In the picture, is a uniformed Russian soldier staring blankly at a local resident. This remarkable image highlights the immense gap between the "occupier" and the "occupied"; despite the fact that they are sharing a park bench, the space between them is immense, and their gazes reflect the vast distance of two solitudes. As Ermine notes, "…On the surface, the presence of the other is acknowledged, but it is the space between people, at the unstated, unseen level of thought and feeling that is overwhelming in the picture". Poole directs our focus to that space and invites us to explore this space as an analogy of the distance between entities - between people and cultures when physical and philosophical encounters of Indigenous and Western worlds takes place" (Ermine, 2007, p. 194-195).

This gap between the "occupier" and the "occupied" reminds us of a defining image of the history of Indigenous insurgency in Canada. This photo of a Canadian soldier and an Indigenous protester during the standoff at the Kanesatake reserve in Oka, Quebec in 1990 (Komulainen, 1990) captures the magnitude of the cultural divide between two nations at this time.

The boundaries of education that exist between the dominant society of Canada and Aboriginal peoples are hindering the development of the ethical space to negotiate and apply "concrete arguments and concepts" (Ermine, 2000, p. 140) for 'best' solutions across this vast cultural divide. The interaction between Indigenous and non-Indigenous people has been conducted through the lens of 'coercive tutelage' in which Indigenous people have been perceived as having little or nothing to contribute to the understanding of human life and how to sustain it. This conversation has often taken on the ethics of domination as demonstrated in the iconic photograph taken at the Oka crisis in 1990. Ermine and the Marshall propose the ethical foundations for a transcultural conversation and dialogue. For the rules of engagement, we turn to the philosophy of the Guswenta and the Gayanashagowa for guidance.

Guswenta Space

"Guswenta", commonly called the Two Row Wampum describes the ethical nature of the relationship between the Haudenosaunee and the early European settlers. This relationship is depicted using a beaded belt that shows two parallel rows of purple beads separated by three rows of white beads and surrounded by several rows of white beads outside. The two rows represent the particular European nation and the Haudenosaunee who are together on the river of life. The ethics of the relationship between the two are embedded in the three rows of beads: peace, respect and friendship. The Guswenta is commonly interpreted as a statement of coexistence built in an ethic of political and cultural sovereignty and non-interference. While this interpretation is important, the wampum also represents a context that promotes an opportunity for meaningful dialogue and learning between Indigenous and non-Indigenous people and knowledge systems.

Newhouse (2008) notes that the space between the two rows creates both an ethical space for a conversation and the ethics governing the nature of the conversations that occur in the space. The conversation is to occur between friends, based on respect and with the goal of advancing the peace through engagement across cultural and social divides. The Gayanashagowa or the Great Binding Law provides some guidance on how we might converse with each other. The Gayaanashagowa sets out the quality of mind that is needed to engage in a transcultural conversation[4]. The conversation does not require one to enter and give up their identity but to engage with a 'Good Mind'. In Iroquoian philosophy, the mind consists of reason and passion (Newhouse, 2008). Conversations engage both reason and passion and hence one is expected to use reason to guide and balance the passions that engulf all of us. Engaging in an ethical conversation in Guswenta space does not require one to give up their ideas and cultural identity but to demonstrate a willingness to engage openly, honestly and with a good mind. Vachon (1995) reinforces Guswenta space as a space for intercultural conversation.

Ermine (2007), Marshall (2012) and Newhouse (2008) together create an ethics of dialogue that if engaged, can foster the development of an openness to the engagement of Indigenous worldviews and ideas in advancing the creation of a culture of sustainability.

Fostering the Dialogue in Sustainability and Management Education

The complexity of creating sustainability cultures requires that one bring together a variety of different knowledges with a view to developing what Newhouse calls 'complex understanding (Newhouse, 2004). New understandings occur through the interaction of the knowledge holders who enter into a dialogue with each other. The goal is to see from the other's knowledge and perspective and in the process perhaps gain new insights, new knowledge or understandings which may lead to contributory actions towards sustainability.

The term 'dialogue' originates from the Greek word *dialogos,* which describes the process of the flow of meaning (logos) through conversation (dia). The physicist David Bohm characterizes dialogue as a sustained collective inquiry into the assumptions, certainties and processes that structure everyday experience; a mindful exploration of embodied meaning, and a collective learning discipline (Bohm, 1990). Building on Bohm's work, Bill Isaacs describes dialogue as a discipline of collective inquiry and a process for transforming the quality of conversation (Isaacs, 2003). Bohm (2008) and Isaacs (2003) address dialogue as part of an inquiry into the challenges and possibilities of transformational processes of human communication, the barriers that keep us from listening to one another, and how we can transcend barriers to mutual understanding.

Bohm (2008) suggests that a tacit or unspoken level of deeper communication that can develop over time in a dialogue group has the potential for bringing fundamental changes in shared understandings and actions. He describes a series of conditions that can enable this qualitative change to take place. The suspension of assumptions is a central characteristic of his notion of dialogue; unlike ordinary group conversations or debates (Bohm, 2008). Dialogue does not involve the process of trying to 'win' or persuade others to change an opinion or position; instead it is characterized by attempts to suspend existing judgements and certainties and engage in mindful exploration. In this regard, dialogue is an intentionally non-conclusive, non-judgemental process that replaces static positions with a commitment to surfacing and then suspending core assumptions to learn about the perspectives of others.

This suspension of judgement is perhaps the most crucial and challenging stage of the dialogue process: 'Accepting this…creates the space for mindful exploration and inquiry from outside of personal positions, enabling group members to, "…stand beside the tension of the topic without being identified with it" (Bohm, 1996, p.8). The challenge is to 'stand beside' without being identified with it. The Haudenosaunee idea of the Good Mind provides us with a frame for doing so (Newhouse, 2008). The Good Mind requires an attention to both reason and passion; It does not say to prejudice reason over passion, but it recognizes both of these human qualities as important and central to learning. Suspending judgement means keeping our emotions at bay and recognizing them as part of the dialogic process at the same time. As noted by Ermine (2007) and Marshall et al. (2012), configuring the dialogic space as an ethical space means that there are ethical rules to be followed if one is to be able to gain new knowledge. Our emotions may be expressed as the fear (of the unknown) or as the joy of the exploration and possibility. In either case, they cannot be dismissed but rather accepted as part of the dialogic process.

This characterization resonates strongly with our own experiences in the classroom, where meaningful conversations can be likened to a "stream of meaning" flowing among, through and between our students. A successful dialogue process makes it possible to create a flow of meaning in and through the entire group and can serve as a catalyst for the emergence of new shared understandings. In our classroom sessions, we find that a dialogue process can often promote a qualitatively distinct level of student engagement that can help them successfully negotiate journeys across cultural and social divides, fostering a deeply personal learning about social diversity and inequalities and cultivating an ethos of social responsibility. There may be no answers that flow from the dialogue but there are possibilities that may emerge and can be taken up in other places. The dialogic classroom becomes a place where dialogue can be engaged on a small scale.

Transcultural Education as a Catalyst for Change

The process of education is a process of encounters with the paradigms and thoughts that shape a particular discipline. One of the purposes of education is to help students understand the way the world works as envisioned by the particular discipline they are studying. Our degree exits requirements test the students' ability to reproduce what has come before with a bit of flexibility and creativity just enough to ensure that the paradigm remains intact. We are learning that this traditional western approach to management and sustainability education is insufficient to produce the change that Holthaus argues is necessary. Indeed, many in the mainstream organizational literature (Hart, 2012) have argued for new transdisciplinary approaches. We believe, based on our experiences, that transdisciplinary approach is not sufficient, as it still systematically excludes the knowledge of Indigenous peoples. If management and sustainability education is to contribute to the culture of sustainability, it needs to find a way to include these knowledges.

Holthaus argues that a culture of sustainability isn't built through large 'quantum' projects but through the deliberate cultivation of 'smallness' (Holthaus, 2008). His view is consistent with the organizational change research on the nature of emergent change processes in social systems (Morgan & Zohar,1999). Most quantum change occurs incrementally, as a result of relatively small individual and group level mindsets and actions that can redirect shared cultures of understandings in a new direction and reverberate and cumulate in their effects. Similarly, large scale cultural change can be triggered through the creation of a small number of projects that connect with each other so that a critical mass of sustainable ideas and understandings emerges within our shared cultural fabric. Telling others of our efforts helps to change the stories that we tell each other. These stories become agents of small-scale incremental change at the level of individual understandings and taken together, foster a sustainable culture. The stories that bring Indigenous and western knowledge together are often invisible until they are surfaced and explored. This invisibility is a large factor that hinders the incremental emergence of a large-scale transcultural dialogue in the classroom.

The classroom is an example of the smallness. It presents an opportunity to bring new knowledges to the table, to change the stories that we tell each other and, in the process, create individuals who know how to work effectively with multiple knowledges. In our view, this ability is one of the key skills necessary for good work in the twenty-first century.

What Have We Learned

We teach undergraduate and graduate courses on sustainable enterprise and management thought. The teaching spaces we create are transcultural spaces in which they bring together different sets of knowledge from different knowledge traditions and start a conversation between them. Learning in transcultural spaces requires a different orientation and a different set of learning skills. These skills involve the ability to learn from the dialogue (as well as from reading and action), the ability to listen and suspend judgement until one understands what one is hearing, etc. Learning in a transcultural space requires an openness to differences and also necessitates rules for engagement and preparation of the mind. It requires what Newhouse calls a Good Mind (Newhouse, 2008).

Our classrooms are not lecture spaces focussing on the one-way transmission of information from the professor to the student. We deliberately frame our courses as discussions with a wide variety of materials that the students may not have encountered before. We pose a question or provocation and seek answers to it through a process of dialogue, that can be roundtable, chaotic, or sometimes using a talking circle approach. We provoke and stimulate and encourage students as they listen to other opinions and perspectives and other knowledges. We place contrasting views side by side and ask students to choose or to find the common elements. This educative process is designed to help them listen to others and to express themselves coherently and cogently. We deliberately do not provide answers, an unsettling situation for students but one that mirrors real life; sometimes it takes time and effort and more dialogue to agree upon answers and sometimes there are no answers, only more questions, which can be deeply upsetting for some students. Students discover that learning comes from listening and engaging in the dialogue process and that developing a complex understanding means the possibility of creative and innovative insights, thus, they learn how to use their good minds.

CONCLUSION

In this chapter we argue that educating for a sustainable future and learning to live within our planetary limits is vital of our times. We believe this complex endeavour requires an educational approach to management education that transcends traditional discipline-based, mono-cultural inquiry. None of the significant challenges that we face now can be solved with the mindsets, worldviews and tools of a single discipline or cultural perspective. We strive to integrate multiple worldviews, perspectives, dimensions, approaches, and disciplines in both the content and pedagogy of learning experiences in management education. In contrast to dominant western educational narratives, pedagogies, and curriculum developed for sustainability-related disciplines, we argue that a transdisciplinary approach that brings together Indigenous and western scientific knowledges and ways of knowing offers qualitatively different opportunities and challenges for successfully engaging these core issues. We further argue that bringing together Indigenous knowledges and Western knowledges in a transdisciplinary approach provides a promising and unique context that can potentially build the mindsets, knowledges, skills and dispositions that are needed for living and managing sustainably in our challenging times.

We find that this transcultural approach equips learners with a unique perspective for revisiting, questioning, and reframing the overall context of managing and organizing for a sustainable future. By positioning Indigenous Knowledges worldviews and practices alongside of traditional western approaches to management, the process of surfacing and questioning the underlying values, beliefs, and culturally embedded assumptions about the nature and purpose of organizations can potentially become more accessible, productive and rewarding. A pedagogy grounded in these principles can promote student interest and engagement across cultural and social divides, and foster successful learning about bridging social inequalities, and cultivating an ethos of social and environmental responsibility.

This educational approach presents a potentially successful response to the growing need for educational approaches and practices that prepare students to live, work, and lead in a complex, diverse, and increasingly divisive and stratified society. We have described how we have leveraged this approach to extend, deepen and embellish the dialogue surrounding Canada's urgent need to transform its higher education systems into centres of thought leadership as part of Canada's Reconciliation. We believe that embracing the ideas of a transcultural narrative building on Indigenous and western knowledges can help us foster learning communities that can inspire the creativity, innovation, and social responsibility needed to to lead us through our collective journey in these challenging times.

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KEY TERMS AND DEFINITIONS

Bimaadiziwin or Mino-Bimaadiziwin: Translates from Anishinabemowin as "fostering the good life." A good life is one that is balanced between the physical, emotional, mental and spiritual aspects of life.

Dialogue: Dialogue can be characterized as a collective learning process that involves sustained inquiry into the assumptions, certainties and processes that structure everyday experience.

The Gayanashagowa or Great Binding Law: Developed in 1140, this law brought together five constantly warring Indigenous nations into a confederate league whose purpose was the continual pursuit of peace. It paid particular attention to the quality of mind necessary for leadership in bringing the five culturally different nations together.

The Good Mind: The good mind is the quality of mind that is to be used in decision making by the Haudenosuanee leaders. It is a mind guided by reason and balanced by passion with an ever-present desire to create peace.

The Guswenta: The two-row wampum belt sets out the principles for the relationship between the Haudenosaunee and the Europeans. These principles are peace, friendship and justice.

Haudenosaunee Seven Generation Rule: Asks that decision makers consider the needs of those living seven generations from now. The future is conceived of as the set of faces coming towards us, grounding our relationship with the future.

Indigenous Knowledges: Includes ancient knowledges that have been transmitted from one generation to the next through millennia; spiritual knowledges that are practiced through ceremony and everyday living; land-based knowledges and empirical observations that are grounded in particular ecologies, both rural and urban; and the ontologies and epistemologies encoded in Indigenous languages that shape perceptions, ideas, and knowledge creation practices.

Transcultural Education: A pedagogy aiming to engage learners from different cultures and knowledge traditions with the purpose of guiding them through ideas and processes of working together in a way that respects differences, acknowledges common ground, and seeks to co-create new knowledges.

ENDNOTES

[1] Bimaadiziwin or more precisely mino-bimaadiziwin translates from Anishinabemowin as 'fostering the good life'. A good life is one that is balanced between the physical, emotional, mental and spiritual aspects of life.

[2] Ubuntu has a variety of meanings but its most common one is 'I am because we are'.

[3] The medicine circle (or sometimes medicine wheel) is a graphical circle representation of the nature of social reality, the structure of Anishinaabe society and Anishinaabe values.

[4] The Gayanashagowa or Great Binding Law, developed in 1140, brought together five constantly warring Indigenous nations into a confederate league whose purpose was the continual pursuit of peace. It paid particular attention to the quality of mind necessary for leadership in bringing the five culturally different nations together.

Chapter 7
Urbanization and Its Implication for Sustainable Development in a Circular Economy:
In Particular Food Production

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ABSTRACT

Only about 25% of the world's land area and soil can be viewed as sustainable for agriculture. The rest of the soils are too dry, too wet, steep, rocky, cold, shallow, acidic, alkaline, or saline to allow the growing of crops. The major problems lie on the harshly increasing need for agricultural products due to rising populations as well as to the world desire to attain ever higher living standards. Food shortage, increase in toxic chemical in production, and urbanization are three inseparable things. One way to solve food shortage is to increase agricultural production. However, increase of agricultural production involves a package of measures that must be fitted to the specific situations in each case. Those measures are the use of high-yielding crops like cassava and varieties and a set of treatments designed to optimize growing conditions. Among such treatments is the use of nature-based solution like the use of cassava waste in feeding of livestock, use of cassava waste as a manure, minimizing losses of water and nutrients due to runoffs.

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INTRODUCTION

The urbanized world has led to social, economic, and ecological sustainability into progressively challenged surroundings, which require the exploration on their intertwined connections, especially in the rapidly rising nations. A progression of eco-environmental problems, like resource consumption, biodiversity, climate change, and environmental debasement have risen and sprawled (Chen et al., 2016). *Urbanization is defined as the demographic procedure whereby an increasing share of the national populace lives inside urban settlements.* All throughout history, urbanization has been a key power in human and economic development (Mohamed et al., 2014). *Whereas sustainable development is improvement that delivers fundamental ecological, social and economic services to all residents of a group without undermining the viability of the natural, constructed and social frameworks whereupon the distribution of these services relies* (Kates et al., 2016).

As indicated by a report by the United Nations (2010), the proportion of urban populace ascended from 13% in 1900, to 29% in 1950, to half in 2009, and it is anticipated to be 69% in 2050. Urbanization brings numerous advantages, such as diversity, market effectiveness, jobs, education, and health improvement. It is these advantages that draw in a persistent stream of individuals from rural to urban regions, which is now in turn undermining agriculture due to migrations. However, because of the fast pace of urbanization, regular environments are progressively supplanted by urban communities. It has been progressively noticed that urbanization prompts numerous issues and these issues present hindrances to accomplishing sustainable development. In accordance with these developments, sustainable urbanization is advanced as a vital part of sustainable development. An urbanization procedure that satisfies the standards of sustainable development portrays sustainable urbanization (Liyin et al., 2012).

As already mentioned above, only about twenty-five percent of the world's land area and soil can be viewed as sustainable for agriculture. The major problems lie on the harshly increasing need for agricultural products due to increasing populations as well as to the world desire to attain ever higher living standards. Food shortage, increase in toxic chemical in production to meet the need of the populance and urbanization are three inseparable things. One way to solve food shortage is to increase agricultural production either by extending the area under cultivation, by strengthening production on chose tracts without further extension or by utilization of high-yielding products and assortments, and an arrangement of treatments intended to improve growing conditions (Daniel et al., 2013). One example of a high-yielding crops is cassava. Cassava is recyclable. It is mostly seen in tropical areas of the world like Brazil, Caribbean, Nigeria, Ghana and some parts of Africa. It is a turberous starchy root and called Manioc. Cassava production contains no chemicals; it is a nature-based food production process; it is economically viable and protect public health through its nutrient supplements. Cassava waste can either serve as manure or food to livestocks like the pigs, Goats, cows etc. Example of food produced with cassava according to the south-East Nigeria are garri, Fufu, African Salad etc. (Rodriguez, 2017).

In any case, rural profitability and productivity should be sustainable. To accomplish this, there is a requirement for waste reduction and enhancing resource and energy utilize effectiveness all along the chain of nourishment production, processing, storage, dissemination, marketing, consumption, and waste reusing, while at the same time guaranteeing food security and keeping up environmental quality. These tasks are made significantly even more overwhelming since they should be proficient at the same time decreasing ozone depleting substance outflow and reacting to changing climate conditions. The principal challenge here is to accomplish congruity between the duties and requirements of developing and developed countries, between the necessities of our age and those of future generations, and between the human species in general and other species in the community of life on Earth (Daniel et al., 2013). To explain the purpose of this paper, which is the use of nature-based solution like cassava waste as manure in agri-farming and in feeding the livestock's which in turn can be reused as manure in food production in order to reduce the use of toxic chemicals like fertilizer in production system of cassava, this paper is divided into three sections: section 2 talks about the link between urbanization and sustainable development, industrialization and its impact on food production; section 3: discusses the approaches to sustainable cultivation of Cassava while section 4 discusses the sustainable factors of Cassava.

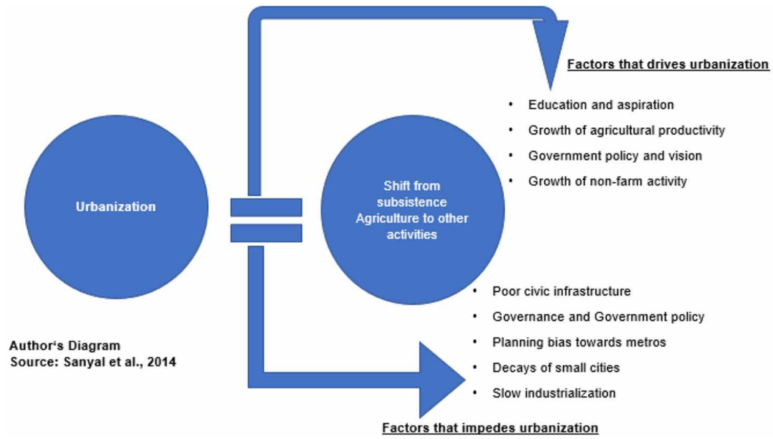
URBANIZATION AND SUSTAINABLE DEVELOPMENT

Without precedent for history, more than half the world's kin are urban. Amongst now and 2030, the world's country populace is expected to remain to a great extent static, while the urban populace is anticipated to develop by 1.5 billion individuals. By 2030, 60% of the worldwide populace will live in urban areas. More than 90% of that urban development will happen in urban communities and towns of the developing world, for the most part in Africa and Asia. The urbanization of the worldwide populace has crucial repercussions for the economy, society and the earth. Currently, urban centers cover just a little piece of the world's land surface that is, about 0.51% of the aggregate land territory. However, urban territories will grow essentially amid the following few decades. Based on current information, urban land cover will increment by 1.2 million km2 by 2030, tripling worldwide urban land region approximately 2000 and 2030. Urban communities cover a little piece of the world, yet their physical and biological footprints are significantly bigger. Urban areas represented 82% of worldwide GDP in 2014 and by 2025, this will ascend to an expected 88%. There will be 230 new urban areas at that point, all in middle wage nations. One hundred urban communities in China alone may represent 30% of worldwide GDP by then (UNDP, 2016).

Furthermore, urban communities create more than 70% of the world's greenhouse gas (GHG) outflows and utilize 80% of the world's vitality. The International Energy Agency estimates that urban vitality related GHG emanations will ascend from around 67% today to 74% by 2030 (UNDP, 2016). Urban communities also have the greater part of the world's basic framework, key development resources, political organizations and major socioeconomic activities. Worldwide examinations of climate change and debacle impacts demonstrate that a high extent of the general population and economic activity influenced by outrageous climate events is focused in urban centers. Urban areas' defenselessness goes beyond exposure to climate change effects and outrageous events. Brutality and crime are pressing issues in numerous urban zones. The urbanization forms in developing nations is frequently ineffectively overseen, resulting in biased, exclusionary and divided urban communities and expanded danger of savagery, particularly among disappointed segments of the urban populace that cannot get to the formal political framework, including exiles and 'Internally Displaced People' (IDPs) (UNDP, 2016). Also, urbanization characterized above is basically a move from subsistence agriculture principally determined by an expansion in instructive and aspirational levels, development of agrarian profitability, engaged and deliberate government approach and development of non-farm activity. While on the other hand as illustrated in the Figure 1 below, the variables that prevent the move from subsistence agribusiness to other economic activities and accordingly obstruct the procedure of urbanization include: poor city framework, absence of engaged and deliberate government strategy, a planning predisposition towards metropolitan centers of development, the rot of residential areas and the slow rate of industrialization etc. (Sanyal et al., 2014).

For quite a while, the cooperation amongst urbanization and sustainability is epitomized in biological sustainability, which is firmly connected to universal urban sprawl and social sustainability associated with persistent urban populace development. In an environmental sense, the previous several years have seen a boundless urban extension in developing nations, for example, China and India. Such development has put gigantic strain on its supporting environmental frameworks. Impenetrable lands, for example, settlements and thruways have sprawled quickly with the cost of cropland, timberland, wetland, and different grounds with high biological esteems in urban regions. For this situation, in spite of the fact that the urban scene has been changed into a reasonable pattern in terms of its network and compactness, the biological habitat is incredibly challenged on the grounds that the

Figure 1.



urbanized landscape significantly influences the related environmental procedures and services (Zeng et al., 2016). However, stemming the procedure of urbanization, putting strict controls on relocation and rushing to villages are not the answer for accomplishing ecological sustainability. According to this researcher, the pivotal elements deciding the biological impression of a city lays in its thickness of populace, total territory utilized, urban shape, transport framework, constructed environment/ structures, vitality supply/use/sources, water supply/utilization, waste generation and management etc. (Sanyal et al., 2014).

Link Between Urbanization and Sustainability

Urbanization brings numerous opportunities, for example, differing qualities, market yield, jobs, literacy, and health improvement. It is these advantages that draw in a consistent stream of individuals from provincial to urban territories. However, because of the fast pace of urbanization, characteristic biological systems are progressively supplanted by urban communities. It has been progressively noticed that urbanization prompts numerous issues, for example, air and water contamination, exhaustion of developed area because of urban sprawl, worldwide environmental change, and others. The standards of sustainable development have been progressively connected over all sectors, with the advancement of different management frameworks. For instance, the Building Research Establishment Environmental Assessment Method (BREEAM), the Leadership in Energy and Environmental Design (LEED) and Green Star has been connected to enhance ecological execution. Corporate Social Responsibility (CSR) has been elevated as a system to enhance social sustainability. Governments have upheld different strategies on sustainable urbanization, and current research has additionally acquainted different methodologies to help with advancing sustainable urbanization. A few scientists likewise have built up an integrative structure to comprehend concerns with respect to sustainable urbanization from the points of view of economic, social, political, demographic, and ecological exhibitions. As a dynamic procedure, urbanization brings changes of physical development, governmental issues, and culture to a city while fulfilling the needs of an increased urban populace (Shen et al., 2012)

Furthermore, it was contended that urbanization is personally identified with economic development, human welfare, and significant changes in social association and examples of human conduct, exhibiting both opportunities and challenges to accomplishing urban sustainability. Urban sustainability can be viewed as a measure for surveying the degree to which a city has accomplished a desirable state of sustainability. This state is portrayed as a practice that uses resources productively and enhances the quality of life in an excellent environment within the imperatives of our earth. Thus, sustainable urbanization is acquainted to describe a process of urbanization that satisfies the standards of sustainable development. This procedure is additionally a technique for approach intercession to accomplish better sustainability in urbanization. Since urbanization is a dynamic process, the execution of its sustainability varies at various phases of process. Past studies propose that a compelling method for assessing a dynamic process is to compare different values of stages in the process. In this way, a sustainable process of urbanization can be characterized as a dynamic process that empowers urban sustainability to enhance or to keep up a specific level of practice throughout urbanization (Shen et al. 2012). Urbanization is an unavoidable piece of development and is the spatial mirror of the shift away from subsistence agriculture. All the more essentially, the ecological expense of conveying a high standard of living to a rural inhabitant can be high. Mainly, limiting the process of urbanization, putting rigid controls on migration and moving to rustic areas is not the answer for accomplishing ecological sustainability (Sanyal, S. 2008).

Link Between Urbanization and Industrialization

Industrialization prompts urbanization by creating economic development and opening jobs that attract individuals to urban communities. Urbanization regularly starts when a processing plant or different industrial facilities are built within a district, in this way creating a huge demand for factory work. However, different businesses, for example, building producers, retailers and service providers then follow the factories to meet the item needs of the laborers. This generates more employments and requirements for lodging, subsequently setting up an urban zone (Investopedia, 2018). Also, as industrialization prompts economic development –

economic development simply implies an expansion in the limit of an economy to deliver merchandise and enterprises, contrasted from one timeframe with another - the interest for the enhanced training and public works organizations that are characterized for urban zones increments. This is so since organizations searching for new innovation to expand profitability requires an informed workforce, and tenable living conditions attracts talented laborers to the zone. In any case, once a region is industrialized, the procedure of urbanization proceeds for a longer timeframe as the region experiences a few periods of economic and social change. For example, looking at nations like Bangkok, situated in a lesser-developed nation, with an American city, for example, Los Angeles and a European city, for example, Berlin, every one of this urban communities has a dynamically more elevated amount of social, environmental and economic flourishing accomplished through expanded training, government intercession and social change (Investopedia, 2018).

Thus, one of the key difficulties here is that as industrialization stops, the procedure of urbanization proceeds for a longer timeframe causing gigantic number of individuals living in ghettos looking for greener pastures in urban areas. Additionally, demand for food production to address daily needs of individuals expands prompting increment in synthetic substance in food through its preservation procedures and utilization of fertilizers for faster preparations, which thus imperils human well-being. *The term urbanization alludes to the procedure of individuals relocating from provincial zones, for example, villages and towns to expansive urban communities forsaking arable grounds for cultivating looking for occupations in urban communities. While industrialization essentially alludes to the way toward moving from hand production to machine production.* This achieved numerous progressions within the society and the economy of a nation. One noteworthy aftereffect of industrialization was the ascent of capitalism, where cash and huge organizations assumed an immense part in the administration policies. Science and technology were two different areas that got the most conspicuousness, with numerous new inventions being established amid this period. Beside all, industrialization additionally has numerous negative impacts including environmental abuse etc. (DB-Difference Between, 2018).

As specified above, industrialization has advanced urbanization as well as influenced social structure and social establishments. Its one effect is seen on expanding the significance of particular education, which thusly, has influenced the age for marriage. Matured and adult adolescents put off their marriages until they finish their education and settle in life. Post-pubescence marriages then influence conjugal as well as intra-family relations. People turn out to be more aware of their individual advantages and yearnings. Further, industrialization has offered stimulus to versatility also. Versatility included is basically lateral instead of a checked difference in societal position. Yet, as the laborer in the business accomplishes ability, his societal position likewise changes, though the change is construct more on horizontal than vertical basis (Mondal, 2018). It has influenced the methods for control as well. That is, casual means have offered place to formal means. Industrialization has likewise prompted the development of exchange associations, which have influenced the business representative relations in light of the fact that the associations have concentrated on ensuring the interests and social welfare and standardized savings of the laborers. This has constrained the administration to establish social enactment. Last but not the least, discussing the effect of industrialization, sociologists have likewise called attention to its impact on improvement of methods of communication which has diminished self-reliance of towns, expanded life span of life, and advanced commercialized diversion. Plainly, industrialization has influenced the interests and the estimations of society to such a degree, that people's personality, status, responsibility, and conduct have come to be reshaped and reoriented (Mondal, 2018).

Similarly, even urbanization have two sides of a similar coin-one with beneficial outcomes and the other with negative. Points of interest of urbanization as pointed above incorporates better pay, greater opportunity, better access to offices, etc. While, the negative parts of urbanization incorporate estrangement, exploitation of people, high expenses of living, costly lodging and offices, and indeed, even exploitation of the earth. For sure, both industrialization and urbanization are identified with each other and industrialization is the prong that get the urbanization wheel rolling, however, they are not the same and should not be mistaken for each other (DB-Difference Between, 2018). The connection amongst urbanization and industrialization prompts push and pull factors, which represent the development from towns to urban communities. Of the push effects, first, populace increment implies less employments to go around in the customary farming segment. Second, where agribusiness is getting to be modernized, an absolute lessening in employment happens. Of pull effects, the most grounded one is the possibility of making a better living than a rustic laborer. Second, facilities such as, power, clean water, and instructive, correspondence and recreational will probably be accessible in a city. Third impact is the social fascination of a city, and the marvelousness of the cutting-edge lifestyle, that, maybe is the more profound want of the youthful to become urbanized. Modernization scholars view this procedure as freeing. It is in a city that independence takes birth and blooms and it is here that individual motivates the chance to break conventional limits and accomplish those objectives and goals that give them their very own character (Mondal, 2018).

However, the expanding populace of urban areas disguises more than it uncovers. All individuals flooding into a city cannot get a house, either in light of the fact that they cannot manage the cost of lease or in light of the fact that it is too far from the work-put. This constrains them to live in ghettos. The quantity of ghetto inhabitants in metropolitan regions for example in Delhi, Calcutta, Lagos and Chennai keeps running in millions, unlike their number in huge urban areas like Jaipur, Ahmedabad, Bangalore, Lucknow. Other than an increment in ghetto territories, urbanization additionally has influenced family relations, inter-caste and inter- correspondence relations, status of ladies, rate of crime and adolescent misconduct (Mondal, 2018). Urban planning which supposed to be the ultimate solution, has been skewed in light of the fact that it has customarily mirrored the interests of the intense and white-collar class. The requirements of the majority are never contemplated particularly in developing countries where urbanization is now occurring. The principal factors which have made the urban wreckage as distinguished above may be: inadequate planning, outsider outlines, absence of comprehension and investment in public transport, over-direction, and not including private offices in planning and building. The answer for diminishing the development of urban communities lies in creating ring towns that is, fortifying public transport offices with weight on decreasing private vehicles yet accelerating public transport. For example, in Mumbai, the rural trains have figured out how to broaden the city's rural areas of 120 kilometers away (Mondal, 2018). Urbanization acquires changes in work-drive structure too that is, individuals occupied in essential (agribusiness), secondary (assembly) and tertiary occupation like exchange, transport, public organization, banking and different administrations and in country urban efficiency. For example, taking the instance of West Bengal, the rate of urbanization in the state in the vicinity of 1951 and 1991 was ease back in contrast with Maharashtra, Gujarat, Tamil Nadu and also all India level. This influenced the circulation of workforce in all the three segments: essential, secondary and tertiary in those states. With all these negative effect, feasible improvement must be accomplished through change, re-organizing and re-planning the entire framework mostly in the developing nations that are quick emerging into urbanization (Mondal, 2018).

Impact of Urbanization in Food Production

An assortment of past investigations had analyzed the effects of worldwide advancement on food production. These investigations include a wide range of logical orders, strategies, models, and information. Geographic and biophysical appraisals frequently center on the heterogeneity of production conditions and their outcomes. Engineering appraisals in the land utilize area bargain basically with innovative improvement and related opportunities. Economic appraisals take care of ranch level as well as product advertise ramifications of improvement (Schneider, et al., 2011). As definitely known, urbanization gets real changes in interest for rural items both from increments in urban populaces and from changes in their eating methodologies and requirements. This has conveyed and keeps on acquiring significant changes how needs are met and, in the ranchers, organizations, companies, and neighborhood and national economies who benefit and who miss out. It can likewise bring real difficulties for urban and rustic food security (Satterthwaite et al., 2010). As indicated by UNDP program final draft, the greater part of the world's urban development in the following two decades about 92% will be consumed by urban communities of the developing world, which are slightly outfitted to manage quick urbanization (UNDP et al., 2009).

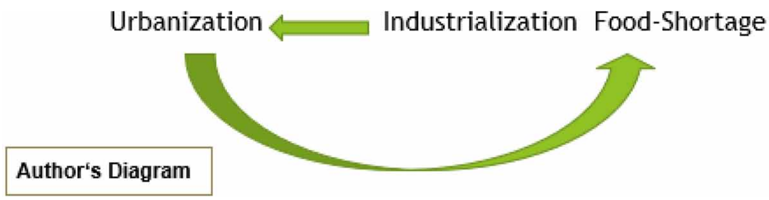
In order words, it is typically accepted that most developing countries will keep urbanizing, but many low-wage countries presently do not have any area of comparative advantage inside the worldwide economy, hence the basis for the flourishing expected to support urbanization (Satterthwaite et al., 2010).

In addition, land and water are basic assets for the generation of food and therefore constitute two of the most basic assets for humankind. These assets are experiencing tension by population development, economic advancement, and environment change; that is the reason while cassava production turns out to be more fundamental in tropical zones since its production requires less water accessibility. Basically, tomorrow's agriculturists need to create more food with less assets. Beyond meeting market requests, worldwide food generation has essential connects to several crucial targets of societies including the decrease of ailing health and destitution, enhanced access to a solid eating routine, better administration and assignment of crisp water assets, expanded utilization of sustainable power source, and the security of climate, environments, and biological variety (Schneider et al., 2010).

Furthermore, the need to secure sustenance for more individuals is confronting agribusiness with the momentous errand of working more economically and gainfully. Quick urbanization, which happens predominantly in rising economies and developing countries, implies that individuals and governments will be confronting gigantic difficulties. For instance, a Nigerian city with four million tenants requires around 3,000 tons of sustenance daily. With a specific end goal to give this amount, two Lorries would have to convey three tons of food to the city at regular intervals. In contrast to rustic locales, food is normally not developed in city zones and it is progressively also no longer prepared there. In terms of food security, city-inhabitants, who procure more on average, are more subject to external elements than the rustic populace. In any case, currently a large portion of the urban communities in rising economies and developing countries do not have the assets to develop urban foundation to keep pace with the fast ascent in populace numbers (Matuschke et al., 2014). The figure underneath is basically demonstrating the push impact of urbanization and industrialization on food production especially agribusiness.

As indicated by CGIAR report, urbanization both compels and gives new chances to farming. As demonstrated previously, recent research reports show that virtually all the future global populace will happen in urban zones; mostly reflective of rustic - urban movement patterns driven by relative job opportunities. Around 35%

Figure 2.



of current urban population development comprehensively is credited to provincial urban relocation. For instance, in sub-Sahara Africa, urban population is expected to triple in the following 40 years. Developing urbanization over the globe, along these lines, has essential push and pull implications for farming research for improvement. Urbanization states push factors on food production by going after assets required for rural generation, which suggests that quick urbanization has move some of these prolific grounds from farming production. Moreover, increment water and vitality needs from developing urban communities put further constraints on agrarian production in numerous territories. Hence, inventing technologies and production frameworks which increment input-utilize productivity in agriculture, remains a high need for research (Regmi, 2014).

However, globalization and urbanization, joined with more noteworthy instructive and business opportunities in urban territories, have also lessened farm labor accessibility in numerous nations. Rustic and urban regions are never again spatially detached given the advances in data and correspondence advances. Ranch work today, faces worldwide rivalry. This developing opportunity cost of labor has especially drawn young people from provincial territories, progressively leaving farming in the hands of rustic ladies. Research and development exercises need to take this rustic feminization marvel into thought and attempt analysis which give a better comprehension of rustic - urban linkages and the changing community level social and well-being net structures as detailed by CGIAR. For instance, rustic groups increasingly rely on settlements from urban territories for their vocations. Thus, provincial transients in urban regions frequently supplement their wages with sustenance acquired from rural territories. Majority of rural vagrants end up penniless in urban ghettos, putting noteworthy weight on public assets as to administration, sanitation, wellbeing and other areas (Regmi, 2014).

Food security as specified above is one of the most imperative push-impact of urbanization. *Food security is characterized as that which exists when all individuals, consistently, have physical and economic access to adequate, protected and nutritious sustenance to meet their dietary needs and sustenance inclinations for a dynamic and solid live.* For example, China's urbanization has developed for almost 70years.

China is a crowded nation and how to ensure everybody has enough nourishment turns into a significant issue. The issue of food security turns out to be more noticeable in China as urbanization develops. This is because characteristic population development conveys weight to nourishment need and the speed of urbanization grows faster and it influences the cultivated land assets become less. The rustic land assets and horticultural labor force decrease systematically as more individuals move to urban communities (Xuebai0606, 2015). Nevertheless, urbanization conveys additionally two prompt effects to agribusiness: the essentially lessen of rural population and land. The circuitous impact is that it could raise the level of rural modernization. The most fundamental importance of urbanization is the lessening of horticultural population as noted previously. It implies the populations who move to urban areas change their identity from producer to purchaser of nourishment. It merits specifying that, aside from the greater part of transients being male, the general population who move among them to urban communities are constantly youngsters and the remaining are the elderly and kids for the most part ladies. Following 5-10 years, the fundamental grain delivering regions of the workforce will successors when these old individuals cannot labor. Therefore, the weight of nourishment becomes more noteworthy (Xuebai0606, 2015).

In addition, the fundamental wellspring of sustenance uncertainty in most cases is access to food particularly because of an absence of monetary means, as opposed to food accessibility. Poor nourishment usage is likewise a critical benefactor because of poor water, sanitation and wellbeing conditions. High expenses for non-sustenance fundamentals implies that urban tenants must extend their wages over a more extensive scope of merchandise, for example, lodging, vitality, transportation, family unit things, training, social insurance and individual things, notwithstanding nourishment. In some developing nations, ailing health in the poorest regions of urban areas and peri-urban zones as of now equals that of negligible rural regions. Urban zones contain numerous subpopulations helpless against nourishment weakness. For instance, a developing issue is the place of young people and adolescents in the social texture (UNDP, 2009). Half of the population living in developing urban communities is younger than 25. Beyond the well-being and lack of healthy sustenance hazard, these youngsters have extraordinary needs and require unique thought as the fate of development. Society needs to guarantee that they benefit from appropriate instructive administrations with a specific end goal to give them structure and maintain a strategic distance from the development of lack of education, culpability - which is already taking its spot in most places of the world - and savagery, particularly when we realize that education is connected to prosperity and is the principal loss in the midst of food insecurity (UNDP, 2009).

In any case, from supportable advancement perspective, without new plans to address fast urbanization, the quantity of individuals living in ghettos lacking access to fundamental framework and administrations, for example, sanitation, power, and social insurance may soar from one billion at present to three billion by 2050. As definitely known, reasonable advancement of urban regions requires incorporation and coordination, and investment to handle land utilize issues, nourishment security, work creation, transportation framework improvement, biodiversity protection, water preservation, sustainable power source sourcing, waste and reusing management, and the provision of education health services and lodging (UN DESA, 2013). In order words, inventive methodologies and investments are required to advance maintainable improvement, incorporating into the world's urban areas. Nourishment generation and utilization should change to moderate the assessed 32% waste worldwide, and to increment by 70% to bolster an extra 2.3 billion individuals who are evaluated to help the total populace by 2050. The fundamental issue, in any case, is to expand nourishment creation while limiting the ecological effect and expanding natural asset utilize productivity, which infers that as sustenance needs shift to more asset-escalated farming items, for example, domesticated animals and diary, considerably more weight will be applied on land, water and biodiversity assets (UN DESA, 2013).

Nevertheless, the open doors provided by developing urbanization, in any case, come with some alert and research needs to analyze these issues. For instance, developing interest for animal-based nourishment diverts rare grain calories in numerous communities toward animal feed and adds not only to rural sustenance instability as well as further contributes to dangerous atmospheric concerns. Expanded domesticated animal production, especially in thick peri-urban settings, has genuine ramifications for zoonoses, underscoring the significance of survey horticulture and urbanization issues through the viewpoint of feasible landscape. Finally, changing eating routine examples do move under-sustained communities to an eating regimen, which incorporates genuinely necessary protein, and smaller scale supplements. However, fortune and inactive urban ways of life joined with diets high in animal protein is currently the main source of developing corpulence and eating regimen related non-transferable ailments in numerous developing nations. Looking for answers for this double wellbeing burden emerging from under-and over-nourishment must be an exploration and improvements need (Regmi, 2014).

APPROACHES TO SUSTAINABLE CULTIVATION OF CASSAVA

Starting in South America, cassava is developed in more than 100 nations around the globe. It is the third most vital wellspring of calories in the tropics after rice and maize. Its caloric esteem, and additionally its capacity to endure dry conditions and poor soils, makes it a key sustenance security trim in developing nations. As interest for sustenance develops, there is a critical need to expand yields in the face of such difficulties as climate change, dangers from bugs and ailments and the need to make cultivation more asset productive and reasonable (Uarrota et al., 2017). Naturally, cassava is a woody enduring shrub, which develops from 1 m to 5 m in tallness. It is accepted to have been cultivated, chiefly for its starchy roots, for 9 000 years, making it one of agribusiness' most seasoned crops. In pre-Colombian circumstances, it was developed in numerous parts of South America, Mesoamerica and the Caribbean islands. By the 1800s, it was being developed along Africa's east drift and in Southern Asia. Cultivating of cassava extended impressively in the twentieth century, when it rose as an imperative nourishment trim across sub-Saharan Africa and in India, Indonesia and the Philippines (FAO, 2013). Yield of cassava has expanded most uniquely in sub-Saharan Africa, which gathered 140.9 million tons – the greater part of the worldwide reap – in 2011. Approximately 1980 and 2000, generation relatively multiplied, from 48.3 million to 95.3 million tons. Cassava in sub-Saharan Africa is developed basically on little holdings by low-pay agriculturists who make almost no utilization of outside sources of info. It is typically developed with different harvests, for example, maize, rice, vegetables, melons, bananas and oil palm. The greatest gains in cassava production since 2000 have been in West Africa, where yield ascended by 60%, from 47 million to 76 million tons. Efficiency has expanded as nations in the sub-region perceived cassava's potential as a modern yield that could differentiate agriculturists' salaries, acquire foreign exchange and produce employments. Development in yield was specifically high in Nigeria and Ghana, within the space of eleven years, the two nations were able to increase yields by 25%, to around 15 tons per ha (FAO, 2013).

Cassava as a Basic Food

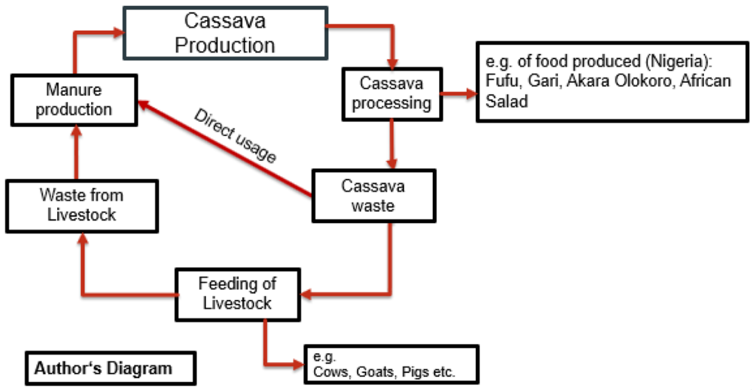
Cassava as a sustenance has about double the calories than that of potatoes and maybe one of the most elevated esteem calorie nourishment for any tropical starch-rich tubers and roots for example 100 g root gives 160 calories. Their calorie esteem originates from sucrose, which represents over 69% of aggregate sugars. Amylose (16-17%) is another real wellspring of complex starches. However, cassava is low in fats and protein than in oats and heartbeats. Regardless, it has more protein than that of other tropical sustenance sources like yam, potato, plantains, etc. As in different roots and tubers, cassava is additionally free from gluten that is the gluten-free starch utilized in unique food preparation for celiac sickness patients (Morgan et al., 2016). Youthful delicate cassava (yuca) leaves are a decent wellspring of dietary proteins and vitamin-K. Vitamin-K has a potential part in the bone reinforcing by invigorating osteoblastic cells action in the bones. It additionally has a set up in the treatment of Alzheimer's sickness patients by restricting neuronal harm in the mind. Cassava conveys a portion of the profitable B-complex group of vitamins, for example, folates, thiamin, pyridoxine (vitamin B-6), riboflavin, and pantothenic acid. It is one of the main wellsprings of some basic minerals like zinc, magnesium, copper, iron, and manganese for some occupants in the tropical belts. Likewise, it has satisfactory measures of potassium about 271 mg for every 100g or 6% of RDA. Potassium is a critical part of cell and body liquids that assist control heart rate and blood pressure (Morgan et al., 2016). Additionally, Cassava leaves contains carbohydrates and also proteins and Vitamin A and are reasonable even for kids' diets (FSN Forum, 2009).

According to FAO, consolidating biological processes and reasonable utilization of mineral compost frames the premise of a feasible product sustenance framework that produces progressively while utilizing less of external sources. For instance, yields in Africa exceptionally, could be notably enhanced if farmers can approach mineral compost at a sensible cost. However, the challenge here remains the incorporation of those small farm-holders without much finance to obtain the mineral compost. The question now is, what about the re-use of cassava waste as a manure thereby making it affordable to all small farm-holders since they produce cassava waste, which they can exchange with the manure at affordable cost with the producing company. By so doing, cassava market will be strengthened (FAO, 2013).

The high-vitality estimation of cassava makes it a very attractive carbohydrate ingredient in animal diet. The low protein substance of cassava tubers about 0.7-1.3% crisp weight is a detriment, confining the utilization of cassava as animal feed, yet this can be enhanced by updating the feed with protein added substances, for example, soybean, or, by utilizing microbial methods or both. Fermentation has been recognized as one of the more affordable methods for expanding the protein nature of cassava and cassava waste. The utilization of microorganisms to change carbohydrates, lignocelluloses and other industrial waste into foodstuffs rich in protein is conceivable because of the accompanying inborn nature of microorganisms namely (a) ability to increase quickly, (b) their agreeability to adjustment hereditarily for development on a specific substrate under specific social conditions, (c) they have high protein content shifting from 3.5-60%, (d) they have development adaptability in both slurry and on solids, and (e) their nourishing esteems are as good as other customary sustenance's rich in protein (Ubalua et al, 2008).

However, the highest capacity of cassava production will not be recognized until production limitations are alleviated in higher-yielding assortments, and until, cassava producers can approach sickness free planting material. Once settled, cassava can develop in zones that get only 400 mm of normal yearly precipitation. However, considerably higher yields can be acquired with more elevated amounts of water supply of around 1700 mm. Cassava reacts well to water system – full surface water

Figure 3.



system has multiplied the root yield acquired without water system; trickle water system can deliver about an indistinguishable yield from surface water system utilizing 50% less water. In Nigeria, root yields expanded six-fold when the amount of water provided by supplementary dribble water system was equivalent to that of the season's precipitation. Supplemental water system that expanded the aggregate water supply by 20% relatively multiplied root yields. In many parts of the world, cassava is only a rainfed crop. In territories with just a single stormy season per year, agriculturists generally plant when the downpours begin. Deferring planting can prompt exceptional yield decreases (FAO, 2013).

Uses of Cassave Waste

Primarily, waste materials from cassava handling (e.g. starch) are separated into four classes: a) Peelings from starting preparing, b) Fibrous by-products from pulverizing and sieving (mash waste), c) Starch residues after starch settling and d) Waste water that is, the emanating (Ubalua, 2007).

Cassava waste are utilized for bioethanol and compost creation, and for cows nourish and sustenance as illustrated in the diagram above. Hemicelluloses are the second most noteworthy segment in cassava waste. Bioconversion of hemicelluloses gets high consideration in light of its advantage in numerous fields, for example, the generation of fuel and chemicals, delignification of paper mash, illumination of juice, absorbability improvement of animals' feedstuffs notwithstanding the generation of developing prebiotics (Ratnadewi et al., 2016). Besides, there are two advances used to change cellulose and hemicellulose to fuel ethanol they are: corrosive and enzymatic hydrolyses. The most widely recognized is corrosive hydrolysis. Corrosive hydrolysis is a compelling strategy utilized for crude material pretreatment in ethanol generation (Srinorakutara et al., 2006).

Nonetheless, the utilization of cassava and its waste in domesticated animals feeding has been restricted, because of the nearness of dangerous cyanogenic glucosides, supplements deficiency, high fiber and fiery content of the peels. Cassava peels hydrolysate could fill in as a decent substrate for the generation of value-added items. There exists an incredible potential in the utilization of microorganisms for the generation of fantastic feedstuffs from the copiously accessible agro-mechanical waste. Cassava peels by ideals of its minimal cost and plenitude in developing countries is thought to be reasonable substrates for microbial fermentation and protein improvement. Handling of cassava waste to meet least prerequisites for fuse into business domesticated animals feed production would surely calm the weight on interest for accessible oat grains (Ubalua et al., 2008). In addition, after cassava root is handled into flour, the remaining mash is called cassava waste mash. It constitutes roughly 11.4% of the crisp cassava, implying that in 2011, the generation of cassava waste mash was around 2.6 million tons. It has generally high carbohydrate content. The starch content is roughly 60% w/w and 61.84% to 69.90% (Srinorakutara et al. 2006), while other constituents 10.61-14.35% is crude fiber and because of the hydroxyl substance of starch and cellulose, a lot of work has been done to adjust those two constituents for different utilizations, one of which is as a superabsorbent. A superabsorbent polymer has hydrophilic gatherings that can ingest and hold liquids and to discharge the liquids later under specific conditions. A polymer is classified as a superabsorbent if its capacity to ingest water is in excess of 100 times its unique weight (Mas'ud et al, 2013).

Impact of Increase in Cassava Production

Throughout the world, cassava enters the market in various diverse structures. Impressive amounts are marketed in crisp frame and bubbled before utilization. Different sums are dried and sold as human sustenance, for instance, *gaplek* in Indonesia or as animal feed. A fermented or non-fermented flour is critical in numerous nations, as *farinha* in Brazil or *gari* in West Africa. A fourth imperative subsidiary from cassava is its starch, to be utilized as a part of human nourishment, as in *krupuk* in Indonesia or *pan de bono* in Colombia or in mechanical applications (Janssen, 1986). A last subordinate of cassava that could have significance is liquor. Amid the 1970's Brazil examined the likelihood of utilizing cassava for liquor production as a substitute for auto fuel. Beside these five item frames, cassava is advertised in an expansive number of other item shapes with territorial or national significance. The diverse structures in which cassava is used show the different parts the yield plays on various landmasses. In Africa, cassava's principal commitment to improvement in the short run lies in its utilization as a subsistence and sustenance security trim. In Asia, cassava handling into starch or animal nourish are of essential significance; also, the yield may assume a part in the weight control plans of the rustic poor. In more exceptionally developed Latin America, cassava needs to gain its pay potential through the market (Janssen, 1986).

Cassava is a vegetative engendered crop. Cassava, being versatile to most soils and atmospheres as noted above seems to be, through its numerous subsidiaries, the staple sustenance of almost 80% of the African populace in general. The advancement of the cultivation of cassava in substantial amounts has taken into consideration the improvement of the quality of rural items gained from cassava and for the improvement of new subordinates like cassava flour for making bread, starch for agro-industries and card board manufacturing plants. This piece of the pie held by farmers has added to the expansion of their pay. Cassava flour is at the root of new foodstuffs in the towns such as cassava bread, doughnuts, cakes and hotcakes. Agro modern plants import a lot of starch, basically from processed cassava. These subordinates of cassava can be delivered locally and could be a wellspring of pay for rural individuals. Cassava is a primary staple sustenance in Africa and a decent wellspring of vitality. However, cassava is deficient in protein and supply mostly carbohydrates. Cassava should be supplemented with other sustenance sources particularly vegetables, legume and oat grains. Taking a gander at the environmental effect of cassava, its greatest effect on the environment is on the soil through water erosion when developed as a sole product; the covering of cassava closes 3 months amid which the soil is uncovered, and dissolved soils frequently end up in the waterways. Nonetheless, cassava is seldom developed as a sole harvest, so this is generally not a noteworthy issue with expanded production under current cultivating frameworks. However, if market for cassava increment and it turns into a sole harvest, this could be an issue although solution to such kind of challenge has been found for instance, in South East Asia and Latin America such challenge has been controlled by different agronomic practices like the utilization of live hedgerows, patio furrowing and zero-culturing (FSN Forum, 2009).

Numerous customary cassava markets experience the ill effects of interest decay because of urbanization and salary development. Fresh cassava utilization per capita lessens in the urbanization procedure, as was demonstrated for Indonesia by Dixon 1984 and for Latin America by Janssen and Wheatley 1985. Nevertheless, similar information recommends that this abatement is not caused by the pay increment and that fresh cassava does not seem to be a substandard decent. Dried cassava for human utilization, for example, gaplek utilization in Indonesia diminishes from rural to urban regions and falls with rising wages, and hence is unmistakably an inferior item. Information from Brazil proposes the same for cassava flour. Dried cassava for animal sustenance has effectively entered the European Common Market and seems to have potential in numerous developing nations in light of the fast development of the animal bolster industry (Janssen, 1986). Cassava starch faces solid rivalry from corn starch, it is so as a result of the developing ability to change substance properties of various starch composes. Expanding the market share of cassava starch will rely upon the capacity to diminish production costs. A significant number of the provincially or broadly critical cassava items also confront diminishing market perspectives (Janssen, 1986).

The primary reaction to the deficiency of nourishment production in developing countries has been to put resources into expanded sustenance creation. For instance, in Uganda, numerous times of investment in crop production advances have produced an incredible number of inventive advances for crop production and insurance. However, the sustenance emergency in Africa has persevered. In recent decade, the International Institute of Tropical Agriculture and national research institutions presented and advanced a broad scope of handling innovations that enables farmers to gather and process cassava into shelf stable value-added items (Abass, et al., 2017). The appropriation of these basic, automated postharvest preparing steps, for example, grinding, chipping and squeezing and innovations, such as the production of top-notch cassava flour and cassava chips were relied upon to expand the demand for fresh cassava in the provincial zones. In addition, they could upgrade agriculturists' readiness to embrace enhanced production advances, especially new assortments, manure and enhanced cultivating hones, which can build cassava efficiency and extend production (Abass, et al., 2017). Another illustration is seen on the research led by Adofu et al; from their work, it is obvious to see that enhanced agricultural innovation improvement has an good monetary effect on cassava profitability as well as the socio-economic liberation of cassava agriculturists from the shade of neediness. It can be said to be the significant panacea through which cassava ranchers can expand production, wage and welfare (Adofu et al., 2013).

SUSTAINABLE FACTOR OF CASSAVA

Cassava is a perishable product that is very vulnerable to decay quickly after harvest. The high perishability requires that it must be prepared into storable structures not long after harvest. The primary items acquired subsequent to dewatering cassava are gari, Fufu, farinha and starch etc. Waste water discharged from cassava handling is acidic with high organic matter content, suspended solids and cyanide and in addition sulfur dioxide. Solid waste delivered from cassava preparing is of three structures namely; peelings from introductory handling, fibrous by-product from pounding and sieving and starch deposit after starch settling. Under most conditions, solid waste does not generate environmental issue (Sackey et al., 2007). Nonetheless, if conditions are not suitable for capacity, issues swing to happen particularly amid times of overwhelming precipitation.

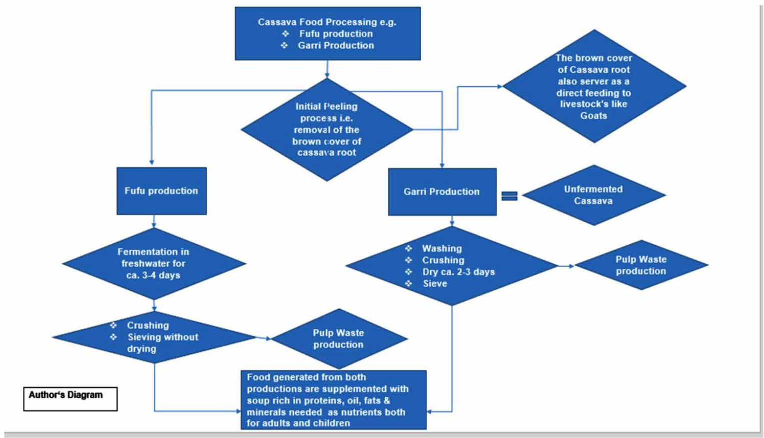
In the dry season, there is little issue with the exception of foul scent. The advances at present for treatment of waste from both little and huge manufacturing plants incorporate land filling of solid waste, utilization of waste as animal bolster, ensiling of solid deposit, maturation of cassava peels, utilization of waste water for water system, invasion of waste water into the soil, stockpiling in oxygen consuming or anaerobic tidal pond and utilization of anaerobic digesters (Sackey et al., 2007).

With the unfaltering increment in cassava production, averaging 3% for per annum since 1995 in Africa and Nigeria, animal feed produced from cassava peels holds gigantic potential. Because of its moderateness, simplicity of capacity and strength to environmental change, this development rate is relied upon to keep, acquiring yearly production in Africa and Nigeria to roughly 350 million and 150 million tons. However, 98% of Nigeria's cassava peels every year are wasted because of imperatives related with drying and worries about security of utilization, especially hydrocyanide and mycotoxins-related sustenance harming. Drying peels outside, practically inconceivable amid the stormy season; therefore, it takes two-three days generally to dry in-doors. Nevertheless, with the assistance of a low-tech methods for changing wet cassava peels into top notch, safe and sterile bolster ingredients within eight hours created by CGIAR researchers, delivering one tons of excellent cassava peel crush from three tons of wet peels is now possible. Africa's and Nigeria's evaluated 50 million and 14 million tons of cassava peel waste every year could produce no less than 15 million and 4 million tons of high-quality cassava peel (HQCP), considerably tending to deficits in the supply of animal nourish and generating a USD 2 billion a year industry on the landmass. Obviously, safe and sterile preparatory measures should be advanced among processors and clients to mollify well-being, storability and other concerns (Okike, 2015).

Cassava Value Chain Analysis ("No Waste")

Cassava fluid deposit contains minerals like nitrogen, carbon, phosphorus, potassium, calcium, magnesium, sulfur, zinc, manganese, copper, iron and sodium which, after anaerobic biodigestion, can at present be utilized for fertirrigation, since the assimilation forms do not generously diminish the mineral substance. Numerous endeavors have been made to total economic incentive to the fluid deposit by thinking about its usage as a compost, herbicide, bug spray, nematicide, biosurfactant or substrate for microorganism development. The creation of biogas, singlecell oil, microbial protein and currently, aromas can be sited as cases of its utilization. *A deposit is a substance coming out from the preparation of a product. It turns into a co-product or a by-product when productive use is made of it. If this is not the*

Figure 4.



situation, the deposit turns into a waste, which is defined as a material with no clear market, social, or ecological esteem, that constitutes an environmental irritation and a wellspring of contamination (Ubalua, 2007).

Looking at the illustration above for instance, Garri, the most well-known of the product, is a dried-out storage cupboard kind of food eaten raw or cooked and it is acquired from the root of cassava. It can be prepared at little, medium or modern scale. The roots are peeled to free them of their external covering and a thicker rugged parenchymatous internal covering. The peels are viewed as waste and generally disposed of and permitted to decay. Crushing of the fermented mash gives out alcohol or juice from the cassava root which is additionally viewed as waste and by-product (Sackey et al., 2007). In order words, the different stages engaged with handling of cassava into gari include: washing of the cassava roots, peeling of cassava tubers, pulping or grinding, maturation and dewatering of cassava mash, sieving, cooking, drying and bundling. After gathering, the roots are washed to evacuate all dirt before preparing to avoid the preface of microorganisms (Sackey et al., 2007).

Garri and Fufu flour provide a high economic value to the producers since it is a food for the masses. The mash from both productions still has a high starch substance as is appropriate for other usage purposes like the generation of a) biogas for warm generation, b) biogas for power generation and c) bioethanol (Trakulvichean et al., 2017). For example: in China Cassava is a decent feedstock to create ethanol since it has high starch substance and it is plenteous in the southern regions of China. Cassava is a starchy food. Starch contained is first condensed with the goal that dextrin and consequently fermentable sugars can be acquired, and, after fermentation and refining, ethanol of 95.6% w/w turns out, through drying out, which is concentrated to 99.5 per cent w/w. In this manner cassava-based Fuel ethanol is delivered, and it is generally denatured by little volume of gas or different materials included to avoid individuals from drinking it (Leng et al., 2008). Thailand being the second biggest maker of cassava on the planet after Nigeria have a 50-75 per cent of worldwide market share for cassava starch. The nation collects around 30 million tone of cassava roots every year, of which 20-25% serve the residential request and the other 75-80 percent serve the worldwide request. The cassava starch industry in Thailand has a high economic incentive because of its request as raw material in various ventures, for example, in the generation of animal feed, food added substances, monosodium glutmates, sugar, paper and fabrics. The generation of 1 tons of cassava starch in Thailand produces around 2.5 tons of mash, with a dampness substance of 80%. The cassava mash is made from starch granules, lingo-cellulose i.e. cellulose, hemicellulose and lignin and other minor parts like the fat, powder, unrefined fiber etc. (Trakulvichean et al., 2017). Apart from the mash, Sonnenberg et al also shows in their research done for the production of oyster mushrooms using fermented peels and stems from cassava crops produced in Ghana that cassava waste i.e. the fermented peels and stems can be utilized well for the production of oyester mushrooms and that generation from substrates containing up to 75% cassava peels equals well to yields acquired on the conventional sawdust-based substrates (Sonnenberg et al., 2015).

In Nigeria, reusing cassava waste produces a triple win for improvement through the joining of easy and complimentary advancements and proceeds with adherence to the procedures of scaling up by enhancing the rural vocations of Nigerian cassava producers and goat herders alike. The preface of an economically reasonable answer for using cassava waste in Nigeria implied also that its waste will no longer be discarded in the conventional way of burning this waste thusly eliminating outflows of carbon monoxide in processing centers crosswise Nigeria (Mackedon et al., 2012). As showed by CGIAR Scientists, changing fresh cassava peels into great, safe and sterile domesticated animals bolster has been shown as actually achievable and economically focused against existing reciprocals. The effect of enhancing the change procedure and scaling up the utilization of cassava peel-based bolsters in Africa, include: a) producing no less than three million tons of top notch feed; b) eliminating of 10 million tons yearly, or 20% of potential cassava peels toxins, from the earth; c) creating 100,000 new occupations—80 percent for ladies; d) establishing another segment of the cassava esteem chain discreetly worth USD 450 million, and given multiplier impact of less expensive agrarian sources of info, African economies remain to profit by up to USD 900 million; and, e) empowering of the private area to autonomously drive expanded uptake of related advancements and item utilizes (Okike, 2015).

Sustainable Development Goals (SDGs) and Cassava Production

Whichever way you take it, cassava is essential for the fate of Africa. Regardless of whether from the viewpoint of handling hunger in a universe of indeterminate atmospheric conditions, as a wellspring of sustenance security when different yields flop, as a way to make money pay through preparing and deals, as a driver of rural agro-industry, as a method for lessening the cost weight of imports through substitution and additionally biofuel generation, or, for some confident lawmakers, as a future fare crop with relative preferred benefit. The FAO says that the world generated 277 million tons of cassava in 2013, of which 158 million tons originated from Africa i.e. 57% and 54 million tons from one nation, Nigeria i.e. 19.5%. None of this African generation is exchanged; all is expended locally (Bennett, 2015). Countries embraced the Sustainable Development Goals (SDGs), an arrangement of 17 optimistic destinations with 169 targets anticipated that would manage activities of governments, worldwide organizations, common society and different foundations throughout the following 15 years (2016-2030). Succeeding the Millennium Development Goals (MDGs), the driven 2030 Agenda is a worldwide vision for individuals, for the planet and for long haul success. It outlines an arrangement for the future – moving the world onto a supportable and versatile course and prompting change in ways of life and to a progress to more comprehensive, dynamic and economical pathways to advancement. The 17 SDGs go for ending destitution and yearning while at the same time reestablishing and reasonably overseeing natural assets. They coordinate the three measurements of supportable advancement – economic, social and environment – with firmly entwined targets. The SDGs are inseparable – nobody objective is separate from the others, and all call for complete and participatory methodologies. Moreover, they are widespread – the 2030 Agenda is as important to developed as it is to developing countries (FAO, 2016).

The Sustainable Development Goals (SDGs) are authoritatively known as “Changing our reality”: The 2030 Agenda for supportable improvement is an arrangement of seventeen optimistic “Worldwide Goals with 169 focuses between them. Among the worldwide goals for manageable Development are: no destitution. This targets completion neediness in all structures and in all groups wherever the following is zero craving. This likewise targets ending hunger by the year 2030. This is to accomplish sustenance security and enhanced nourishment through advancement of sustainable agribusiness. Neediness is a state of being poor. The World Bank (2015) characterizes neediness in supreme terms and sees outrageous destitution as living under USD $1.90 every day and mild neediness as under USD $ 2 daily. It is this case where people’s fundamental requirements for sustenance, apparel and shelter are not met. The area stinks of destitution, since joblessness rate is high and normal procuring is under USD $2 every day in the country. The buying power equality rates of the general population are beneath the destitution line around there. Whereas hunger on the other hand and in this condition is sustenance insecurity. Sustenance insecurity is characterized as an absence of food, requirement for nourishment, craving and covetousness. In a country where there is no broadening, yet the economy is focused on oil, the potentials of the general population will not be tapped for nourishment generation and with the expansion in populace, there will undoubtedly be increment in destitution and appetite circumstance (Udensi et al., 2017).

Taking Nigeria as an occurrence, Nigeria is fundamentally an agrarian country and the nation's financial history and improvement has been firmly fixing to its horticultural division. The current destitution and sustenance frailty circumstances in Nigeria, combined with a mind-boggling populace figure of more than 170 million individuals and contracting arable land territory demonstrate that Nigeria must try harder at creating enough nourishment in the event that she needs to bolster her residents, and in addition meet the United Nations Sustainable Development Goal (SDGs) 1, that is, end neediness in every one of its structures everywhere (Agbachom et al., 2016) and a few scientists has demonstrated that expansion in cassava can help in battling neediness and appetite in Nigeria. For instance: Udensi et al in their research of accomplishing an economical advancement objectives of no destitution and zero craving through the development of cassava in Enugu south local government territory of Enugu state in Nigeria demonstrates that cassava assumes an overwhelming part in the nourishment security of both rustic and urban family units on account of its ability to yield under minor soil conditions and its resistance to dry season and has additionally distinguished cassava as a capable neediness and yearning contender by driving down the cost of sustenance to a million purchasers. Around 84% of cassava generated in Nigeria is expended as sustenance while 16% generation is used for modern purposes in the extents of 10 percent as chips in animal nourish, 5% as syrup focus for soda pops while under 1% is prepared into great cassava flour utilized as a part of bread rolls and confectionaries, dextrin pre-gelled begin for glue, starch for pharmaceuticals and seasonings (Udensi et al., 2017).

In any case, achieving the sustainable development objectives through development of cassava to counteracting yearning and destitution has been obliged because of huge difficulties agriculturists in Nigeria face in cassava generation. Some of these difficulties are those related with their financial status while some have to do with environmental and institutional elements. For instance, it is accounted for that insufficient data about enhanced advancements was one of the significant limitations to ranchers in cassava production. Agriculturists are additionally obliged in cassava generation and handling as far as absence of access to proficient markets. Much of the time, the cultivating family offers their cassava tubers in natural structures to middle men accordingly losing a significant extent of the net revenue accruable at the level of preparing into garri and other cassava items. This is frequently ascribed to the poor state of country roads which makes transportation of fresh cassava and handled items to urban markets troublesome. Mainly, there are various difficulties to cassava production which could be gathered under agronomic, institutional and money related limitation (Udensi et al., 2017). Cassava production has the capability of fighting human craving among grown-ups and babies alike and subsequently will remain a mainstay of sustenance security for the citizenry. The state can improve the situation in the generation of cassava ideally yet the rustic agriculturists' endeavors at expanding the production of cassava has been ignorant with ideas of issues. These issues incorporate insufficiency of assets, defilement among public authorities, absence of present-day correspondence innovations, absence of access to proficient markets and absence of physical frameworks in the provincial regions. It is these important individual, socio-economic and political traps that has prompted their powerlessness to deliver cassava ideally. Against this scenario, it becomes urgent to distinguish methods for enhancing cassava production to diminish neediness and craving in Enugu South Local Government Area of Enugu State (Udensi et al., 2017).

CONCLUSION

Urban farming is progressively predominant in developing urban communities and can supply some sustenance needs and close some salary holes. While it is not a panacea, it can partake in enhancing sustenance security; in any case, numerous legislatures have laws confining urban horticulture that undermine its potential. Developing urbanization in this manner challenges analysts to create input-productive answers for agribusiness, which will add to worldwide nourishment and sustenance security while simultaneously upgrading human and ecological well-being and protecting the natural asset base upon which farming depends. Horticultural research can never again be seen in isolation yet should be seen through a viewpoint that takes a look at the different measurements of flexibility, including local, monetary and social elements, human and ecological wellbeing, and the general network of communities – rustic, urban and worldwide. Obviously enhanced provincial production and market systems would make benefits for both rustic and urban zones. The correspondence amongst rustic and urban families is key here, with urban family units sending money settlements to rustic families in the semi-subsistence segment, which drives the buying of nourishment and different necessities in the rural zones and along these lines adds to the accessibility of a "provincial overflow" of sustenance for transmitting to the urban family.

Subsequently, social networks are one kind of foundation that empowers the stream of products between rural and urban communities. Sustenance security is one of the requirements of stable improvement as showed by sustainable development objectives. However, it needs to take the road of urbanization and industrialization if the nation needs to grow well. Uneven advancement will prompt urbanization and nourishment security clashes while urbanization will be ruined if the sustenance issue cannot be settled. Urbanization should consider the issue of nourishment security. Regardless of whether the opportunities or the dangers of urbanization with respect to sustenance security will prevail will depend critically on how the ascent in economic thriving in urban territories is used. Handling of cassava wastes to meet least prerequisites for incorporation into business domesticated animals sustain production, would absolutely mitigate the weight on interest for accessible oat grains. Increment in cassava production infers increment in cassava waste. The use of cassava waste on the other hand will not only increase food security by more farming and reduce cost of production by incorporation of its waste as a manure but also will create market for their waste, fight poverty and hunger through its jobs provision and at the same time income for small farm holders.

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Chapter 8
Challenges Turning Environment and Sustainability Science Into Policy:
An Interdisciplinary Review

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ABSTRACT

In theory, there is a strong, two-way relationship between sustainability research and public policy that functions in synchrony to identify, understand, and ultimately address ecological problems for the greater good of society. In reality, such a cooperative relationship is rarely found. Instead, researchers and policymakers face a suite of challenges that prevent effective communication and collaborative pursuits, prolonging the period required to address environmental issues. In this chapter, the authors apply a novel interdisciplinary approach to identify key barriers and solutions to translating research into policy. In doing so, the authors present two separate discussions focused on the natural and social sciences. The authors also review established research-to-policy frameworks to develop the new "cohesive" framework. By addressing key barriers between researchers and policymakers, society will be better able to respond to the various environmental stressors that it faces today.

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INTRODUCTION

Researchers and policymakers have long been concerned with the slow transfer of new knowledge into policy. Commonly referred to as the 'research-policy gap', this phenomenon occurs when "the expanding body of research... [is] having little to no effect in practice" (Cohen, Higham, Gössling, Peeters, & Eijgelaar, 2016 p. 319). This is when "more research is [not] needed" (Hering, 2016 p.1), instead a weakness in the science-policy link reduces effective integration of knowledge into action (Pahl-Wostl, Jeffrey, Isendahl, & Brugnach, 2011). As a consequence of this gap, society often struggles to resolve problems in a timely fashion, because the prerequisite information and the mechanism to enact change are disconnected. This problematic gap is widely reported across academic and political sectors including transportation, health care, education, and the environment (see Cohen et al., 2016; Watson, 2005). While all these sectors are critical for a stable and just society, the evolving suite of environmental crises faced by society paired with society's own rapid development and intensification, renders the environment and sustainability (ES) research-policy gap a particularly urgent concern (Watson, 2005).

BACKGROUND

An ES research-policy gap forms when the scientific knowledge required to identify and address an ES issue exists, yet is not reflected in a society's policies. In many cases society values the environment as well as sustainable development — rightly believing future developments should "[meet] the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987 p. 15). Yet these values are not consistently reflected in policies and governance. For example, ES scientists have asserted for decades that climate change is largely due to carbon dioxide released during fossil fuel combustion, with transport alone contributing approximately 14% of the total greenhouse gas emissions (IPCC, 2013). The ES research outlining this issue is widely and freely available. Still, most societies have yet to implement any impactful policies to transition away from a fossil fuel-based transportation system (Covert et al., 2016), despite an increasing global interest in sustainable development (Waas et al., 2014).

While current interest in addressing the ES research-policy gap is high (e.g. Jerneck et al., 2011; Kowarsch et al., 2017), concerns over the limited societal impact of ES research are not new. Radaelli (1995) explains that environmental research "creeps [into] policy...via indirect, cumulative and diffuse processes" (p. 164). Others have claimed that research rarely impacts specific policy outcomes (MacRae, 1976) or lies 'dormant' until important events catalyze policy change (see Sabatier, 1987). No matter the exact mechanism, the slow pace of these processes may be especially unhelpful in a time of climate and other environmental crises, whereby societies are taking huge risks if they count on research findings to be 'taken up' by way of gradual processes.

The barriers preventing research-policy transfers already identified in the ES literature are primarily concerned with communication between scientists and policymakers, with several frameworks proposed as solutions (Hulme, 2014; van der Arend, 2014; Watson, 2005). A consistent conclusion from this work is the need for increased 'interfacing' between researchers and policymakers alike, where science-policy interfaces (SPIs) are "organizations, initiatives or projects that work at the boundary of science, policy and society to enrich decision making" (Sarkki et al., 2015 p. 502-506). These interfaces can take a variety of forms including intermediary discussion forums, joint advisory panels, knowledge networks (*sensu* Dilling & Lemos, 2011), and the establishment of knowledge brokers or boundary organizations (Hering, 2016; van der Arend, 2014; Watson, 2005). While different frameworks purport the efficacy of specific SPIs as *the* solution to the ES research-policy gap (e.g. Hering, 2016; Kowarsch et al., 2017), there is no consensus yet as to which is best. Instead, researchers broadly agree that an SPI with perceived credibility, relevance, and legitimacy can improve the connection between science and policy (Cash et al., 2003). Still others have concluded that changes are needed in terms of how research is conducted in the first place, suggesting a need for sustainability science that spans the boundary of theory and practice, and addresses local perceptions of the research itself (e.g. saliency, credibility, and legitimacy, see Cook & Odom, 2013). While these are all excellent coarse-scale solutions, sustainability issues tend to cut across a range of disciplines with unique fine-scale barriers that need to be recognized and addressed if society is to bridge the ES research-policy gap.

Of the research disciplines addressing ES, two areas of academic study consistently play a prominent role — namely natural science and social science (Turvey, 2015). As ES issues are inherently underpinned by natural processes, natural science is required to delineate the mechanisms causing the issue as well as the mechanisms that could (physically) resolve it. Social science, conversely, is important because modern environmental issues are often triggered by anthropogenic activities (Steffen et al., 2015). Thus, to prevent further incidents or intensification of the issue at hand 'the human factor' needs to be identified, studied, and ultimately addressed (Victor, 2015). Jerneck et al. (2011) argues that there needs to be an equal emphasis on natural and social science in the quest for sustainable development and sustainability in general. Accordingly, the authors posit that by identifying and addressing the fine-scale research-policy barriers for both the natural and social sciences, the ES research-policy gap can be further reduced.

As graduates of Western University's Environment and Sustainability Collaborative Research Program, and scholars in ecology, human and physical geography, as well as chemistry, the authors draw on their own diverse academic backgrounds to provide a unique, interdisciplinary review of the primary problems and solutions most pertinent to the natural and social sciences. The authors were inspired to generate this review after attending frequent seminars and panels discussions with experts in various fields of sustainability that were consistently concerned with how little scientific knowledge has yet to be put into practice. In this chapter the authors outline the main barriers faced by natural and social science and provide potential solutions to facilitate effective translation of ES science to policy. It was not their goal to develop an exhaustive list of barriers, nor to identify barriers that solely apply to the ES research-policy gap. Instead, the authors identified three barriers of greatest concern for translation of natural and social research into policy. Furthermore, the authors review existing knowledge transfer frameworks between research and policy. They complete their overview by presenting a novel interdisciplinary framework to further ease the ES research-policy gap, concluding future scientific efforts need to be conducted with the input and guidance of multiple experts across multiple fields – including policy experts. While the research-policy gap is clearly experienced globally, the authors place much of their discussion in a Canadian context due to their own personal experiences and familiarity with the established systems therein.

THE RESEARCH-POLICY GAP IN THE NATURAL SCIENCES

In the past century, natural science research has successfully contributed to many significant environmental policies, particularly in Canada. For example, seminal research conducted in Canada's Experimental Lakes Area during the early 1970's demonstrated the clear role of phosphorus in major eutrophication events plaguing aquatic ecosystems globally (Schindler, 2006; Schindler, Armstrong, Holmgren, & Brunskill, 1971). Following this discovery, Canada and the United States signed the Great Lakes Water Quality Agreement in 1972, creating a policy with specific targets and mechanisms to drastically reduce point-source phosphorus loading into the Great Lakes basin. In recent decades, however, the research-policy gap has widened considerably in the natural sciences. As recently as 2012, drastic reductions in Canadian federal science funding programs were made, limiting environmental research programs and resulting in the closure of globally significant, federally funded research stations, like the aforementioned Experimental Lakes Area. Wide sweeping changes to environmental legislation propelled natural scientists to protest in record numbers, declaring the 'death of evidence' and a 'war on science' (Turner,

2013) in governmental decision-making processes. Clearly, novel contemporary science-policy barriers have developed in recent decades and are compounded by classical barriers that have remained unaddressed.

Natural Science Barrier 1: Limited Direct Impact on Public

The public tends to demonstrate high resistance to policies addressing issues that do not appear to directly affect them. It is difficult to enact policies that force changes on society when they are not currently experiencing negative consequences (Semenza et al., 2008; Wallinga, Rayner, & Lang, 2015). A case in point is the significant resistance against aggressive climate change policy over the past decades. An individual may not see the point of subsidizing renewable energy or implementing a carbon tax when the only perceived effects they feel on a daily basis are slightly warmer temperatures. It is also challenging to convey the impacts of an individual's action when the consequences feel distant (Pidgeon & Fischhoff, 2011). This distance could be geographical, where citizens find it hard to be sympathetic towards people from a different part of the globe. This distance could also be in terms of time, where people have trouble changing their habits immediately to deter consequences in the future or for future generations. This is particularly true for climate change, where the inherent complexity of atmospheric science makes it difficult to predict exact timelines (Lorenzoni, Nicholson-Cole, & Whitmarsh, 2007). It is important to note that the resistance to ES policies is compounded when there are perceived negative economic consequences associated with said policies. However, economic effects of ES policy are complicated and consistently difficult to anticipate (Riahi, Grubler, & Nakicenovic, 2007). Regardless, if society hopes to move forward on climate change and other environmental issues, it must convince itself to change its behaviour and policies — even when it is not currently experiencing any immediate negative impacts from its actions.

Proposed Solutions

While addressing public resistance to scientifically supported change is a complex issue, there are approaches that can make potential negative consequences resonate with citizens. One approach is to identify the personal hazards of the environmental issue for the public, primarily by conducting research that demonstrates local risks. For example, research by Carlson and McCormick (2015) demonstrated that US cities with established climate change response plans credit research conducted on local climate change impacts as an important driver. Cities like Boston, MA, Raleigh, NC, and Tucson, AZ, had resident academic institutions providing primary data on local vulnerabilities to climate change, emphasizing potential local impacts if adaptive strategies were not developed and employed.

A similar approach was taken to address the ozone depletion crisis of the 70s and 80s. Academic research at the time clearly linked ozone depletion with an increased incidence of melanoma and non-melanoma skin cancers due to elevated ultraviolet radiation reaching the Earth's surface (Fears & Scotto, 1983). The public could clearly identify the potential personal consequences of ozone depletion, particularly in North America, and rightly called for appropriate policies to be put in place (Watson, 2005). Accordingly, politicians developed the Montreal Protocol and Vienna Convention to Protect the Ozone Layer, phasing out the use of ozone-depleting chlorofluorocarbons (CFCs). The successful translation of the ozone research program into policy was attributed, at least in part, to clearly linking the environmental issue with personal risk (Kaniaru, 2007; Watson, 2005). The positive effects of this policy implementation are still being observed to date, as the North American Space Agency (NASA) continues to quantify and report the recovery of the ozone layer over the Antarctic (Strahan & Douglass, 2018).

Another approach is reframing established environmental issues using trusted media sources and social opinion leaders to connect with the public (Nisbet, 2009). Reframing can place an environmental issue in a relevant social context that matches the values of the public. For example, initial climate change findings were intuitively framed as a pollution problem with dire environmental consequences — a strategy used successfully for past large-scale environmental concerns like acid rain. However, this framing was met with resistance by a North American public facing a struggling economy. In response, advocates reframed climate change adaptation as an economic stimulus opportunity, highlighting new job creation and stable employment opportunities (Nisbet, 2009; Nordhaus & Schellenberger, 2007).

Natural Science Barrier 2: Complexity and Uncertainty

Increasingly complex ES problems have widened the gap between scientific research and its implementation into effective policy (Carlson & McCormick, 2015). Both citizens and policymakers are generally uncomfortable with the inherent uncertainty often associated with complex issues. The problems addressed by natural science have increased considerably in terms of their complexity, whereas political systems have stayed relatively constant (Goldson, Gluckman, & Allen, 2014). This has led to difficulty in implementing natural science into policy, and a demand for more sophisticated protocols on how to navigate the differing paradigms across science, policy, and society (Smajgl & Ward, 2013). Scientists have the difficult and fundamentally important role of conveying the probabilistic nature of any complex issue, as well as the concomitant trade-offs of any course of action. Perhaps because this type of communication is inherently challenging, it rarely occurs in practice. This leads to the public potentially overreacting when any problems arise with a given policy without fully understanding the depth of the issue (Goldson et al., 2014). There needs to be a mechanism in which scientists effectively convey the complexities of the science behind a policy in a way that the public can understand and appreciate.

Proposed Solutions

The complexity and uncertainty associated with many of today's environmental issues are generally unextractable from scientific research. Yet, effective communication of these complex ES problems by scientists to policymakers and the public alike is still achievable. Proposed solutions include developing a collaborative network between research teams, government organizations, and non-profit groups with vested interests in the ES issue at hand (Head & Alford, 2015). Such networks allow for a range of experts in relevant fields to discuss and consider each facet of a complex environmental issue. Concomitantly, the network creates a mechanism to effectively translate knowledge directly to engaged policymakers and members of the general public for further dissemination.

Efforts to improve the general understanding of the scientific process would also address this barrier of translating scientific research into policy. The myth that science is supposed to produce unequivocal proof is a fallacy that generates confusion surrounding environmental issues (Sarewitz, 2004). A general understanding that science can only generate evidence with inherent, but *acceptable* uncertainties would provide clarity for many issues (Oreskes, 2004). To address this problem, some now urge technical writers to adapt standardized language when discussing certain levels of scientific uncertainty as a potential solution (Walsh & Walker, 2016), akin to the standardized writing style and terminology adapted for the International Panel on Climate Change reports.

Natural Science Barrier 3: Natural Scientific Literacy

A classic science-policy barrier is the concerning lack of fundamental natural science literacy. Science literacy is widely acknowledged as an essential skill to fully participate as a democratic citizen (Eilks, Nielsen, & Hofstein, 2013), as public opinion can either impede or greatly stimulate policy development and implementation. Many countries that have historically been leaders in scientific engagement and literacy are currently experiencing a significant decline, described by some researchers as a science literacy 'crisis' (DeCoito, 2016; Woods-McConney et al., 2014). For example, between 2003 – 2012 Canada experienced a significant and sustained decrease in high school students' scientific knowledge and problem-solving skills (Richards, 2014). In the United States research has demonstrated "that a substantial portion of the public does not know about basic scientific facts or the essential principles of experimental methods" (Gauchat, 2015, p. 725; National Science Foundation, 2018). As a result of this limited and declining scientific literacy, citizens now often cling to stand alone studies to support their pre-existing opinions, or mistake information written by non-scientists as credible science sources. The rise of social media as a valid information source has resulted in citizens that overestimate their ability to analyze complex issues, and as a consequence doubt the scientific community (Bauer, 2009). This public distrust limits the science-to-policy transfer, as the science lacks public support. This support hinges on the public's understanding and appreciation of the issue at hand, which is often seriously lacking (Miller, 2004). A good example is the ongoing debate on whether climate change is primarily a result of anthropogenic activities. This is an issue that frequently arises in political debate and is therefore discussed extensively amongst the public. The problem of limited scientific literacy shows itself when climate change deniers cite information from a few select studies or from social media sources, when the overwhelming scientific consensus indicates that humans are a main driving force behind recent climate warming (Pidgeon & Fischhoff, 2011). Until the public has a baseline of scientific literacy, policy will continue to be held back by the political pressures created by citizens.

Proposed Solutions

Issues surrounding scientific literacy in the general populace have been long-standing with little widespread success in terms of solutions. The rise of social media as an information source has prompted many researchers to consider social media platforms as not only a threat but also a potential solution to scientific literacy. Initial studies have demonstrated that such platforms are effective at engaging young adults in productive science-oriented debate, which in turn develops scientific literacy (Greenhow, Gibbins, & Menzer, 2015). Others have found social media sites create unique opportunities for experts to communicate directly with the general public. Such interactions increase the general interest in ES issues and create opportunities to advance scientific literacy (Fauville, Dupont, von Thun, & Lundin, 2015). That said this solution is passive, depending on the general public to engage with the scientific community and consume reputable science.

Other researchers argue that scientific literacy issues are secondary to other societal factors, such as group identity. Research by Kahan et al. (2012) demonstrated that groups with similar cultural ideologies can have similar opinions on ES issues, irrespective of scientific literacy. These results were purported to be driven by peer-pressure within the specific ideological groups, as opposed to a mastery of scientific information (Kahan et al., 2012). This issue is further compounded by widespread group ideologies that inherently reject science engagement (Bennett & Hogarth, 2009). Instead the study of science is described generally as “important but not for me” (Jenkins & Nelson, 2005 p. 41). Consequently, as young adults many citizens do not seek out extracurricular science programs and limit their own science education to the bare minimum requirements, with life-long consequences (Bennett & Hogarth, 2009; Woods-McConney et al., 2014). In all cases grassroots movements within resistive groups are needed to disassociate the group’s identity with a specific environmental opinion or capacity for science. Only after this dissociation can increasing scientific literacy potentially be effective.

THE RESEARCH-POLICY GAP IN THE SOCIAL SCIENCES

Historically, ‘environment and sustainability science’ has been housed almost exclusively in the natural sciences. Environmental researchers have recently increased their attention to social theory, in part because what counts as ‘environmental’ is also social, biosocial or natural-cultural (Ingold & Palsson, 2013). The ever increasing societal recognition of humanity’s role in many modern environmental crises has further prompted many academics to investigate the theoretical and practical convergences between society and nature (Descola & Pálsson, 1996). While traditional scientific research still needs to take place to further our mechanistic understanding of environmental issues, social science is uniquely positioned to tackle research questions related to political and cultural barriers surrounding these issues (Hackmann & St. Clair, 2012).

Social Science Barrier 1: Funding

A major barrier preventing socio-environmental research from affecting policy and change is the relatively limited funding of social scientific questions, preventing their initial investigation. Across environmental and other research, social scientists often find it difficult to obtain funding when it is driven by ‘pure’ social research questions (Holm et al., 2013), despite a growing general acceptance that human activity is a key driver of environmental change (Palsson et al., 2013). This is particularly the case when the research does not have any apparent monetary value and/or when “quantitative purists” maintain that survey work is the only acceptable form of social inquiry (Johnson & Onwuegbuzie, 2004; p. 14).

In Canada, federal funding for research is divided amongst three Tri-Council granting agencies: Social Science and Humanities (SSHRC), Natural Sciences and Engineering (NSERC), and Health Research (CIHR). Similar to the way funding is spread in the UK, Australia, and the United States, social science research is given a much smaller percentage of total funds — only 15% in 2014-2015. The total amount of funding provided in Canada in 2016 to projects with titles or keywords that included "environment" or "sustainability" was between 1.4 – 9.2% of all Tri-Council funding (SSHRC, 2016). Given the need for increased research looking at human dimensions of environmental disturbance, these figures are troubling.

Proposed Solutions

Naturally, the simplest solution is to encourage funding organizations to better support socio-environmental research. However, a lack of support in a particular research area is not in and of itself a good reason to increase funding. In order for environmental social scientists to put forth more successful granting applications, they must adhere to current systems and contexts in place today. For example, in light of Ontario, Canada's push to fund research that supports economic growth, academics should make clear to granting agencies the increasing costs associated with unabated climate change. These costs were first detailed by Stern et al. (2006), and Canadian-specific research has since echoed some of the conclusions, including one estimate that warming could cost Canada between \$21 and \$43 billion per year as of 2015 (National Round Table on the Environment and the Economy, 2011; see Nelson et al., 2014). With these types of trends in mind, socio-environmental academics may be better served to emphasize the potential for their research to either mitigate or adapt to global climate change.

Another potential funding avenue for socio-environmental research programs is outside of major traditional government agencies, such as internal sources (i.e. university funding), private industry, or non-profit organizations. One such non-profit group is the George C. Metcalf Foundation of Toronto, Ontario (http://metcalffoundation.com), which has funded socio-environmental research at York University, the University of Waterloo, and Western University in recent years. Although funding from industry in particular can present problems in terms of perceived bias, loss of control, and/or an increased commodification of research (Nelson, 2001; Perkmann et al., 2013), it is also known to create localized knowledge spillovers — an advantage co-located actors experience when accruing and accessing knowledge (D'Este, Iammarino, Savona, & von Tunzelmann, 2012).

Social Science Barrier 2: A Lack of Applied Research

Historically, social science has been largely disconnected from "the practical problems of policy" (Merton, 1949; p. 161), instead focussing more explicitly on social theory development. While theory development is of great importance, it has left a clear informational deficiency for practical social issues. The value of such applied social research pursuits is outlined by Moran and Lopez (2016), who conclude that public involvement in academic research "can ensure that the investments results in public benefit" (pp. 1-2). By strengthening the 'science-policy' interface, it is this public benefit that socio-environmental researchers can advance, yet also use as leverage for additional funding in this area (see Social Science Barrier 1: Funding). The idea that social research should lead to public benefits has led to debates on the distinctions (or lack thereof) between applied social research and activism. Wadsworth (2005) describes the unease sociologists in particular have faced when beginning research that is intrinsically political in nature. In support of applied research, others have claimed that there is no such contradiction between an active commitment to problem resolution and quality scholarly research of that problem (Hale, 2001).

Proposed Solutions

Despite the extended history of social-academic research generally being unapplied in nature, there is some indication that this may be changing. Particularly in the social sciences, Hawkins, Langford, and Saunders (2015) found that applied research is increasing across six Canadian Universities. How exactly the academic community engages in more applied research activities leaves some room for debate. Palmer (2012) suggests social inquiry should begin by asking policymakers and community leaders what they need from the research community. An alternative solution is the involvement of the local community in the research early on. This could mean asking nearby residents to help shape the research questions that are important to them. This type of community-oriented, social science research has given rise to action-based practices like Community-Campus Partnerships (CCP; Boser, 2002), Participatory Action Research (PAR; McIntyre, 2007) or Community-Based Participatory Research (CBPR; Hacker, 2013). These applied research techniques strive to equalize the power dynamic between community participants and academic researchers by capitalizing on valuable local knowledge to invoke societal change and shape policy (Baurn et al., 2004; Freudenberg and Tsui, 2014). While these research programs have been primarily applied in healthcare studies (see Castleden et al, 2012, 2008), they would have great value in addressing the ES research-policy gap if adopted widely by the field. In fact, the main purpose of CBPR is to "[combine] knowledge and action for social change" (Minkler and Wallersetin, 2003), where by greater involvement of the public alters the mechanism for, and in turn leads to greater policy change (Freudenberg and Tsui, 2014; O'Fallen and Dearry, 2002).

While the benefits of applied, community-oriented research programs like CCP, PAR, and CBPR are clear, they are not yet widely utilized. Systematic and institutional norms of research funding and outdated university policies inadvertently discourage this style of research (see Curwood et al., 2011; Schwartz, 2010; Schwartz et al., 2012; Sullivan et al., 2001). Even when such community-academia partnerships do manage to form, there are still biases that favour the interests of universities over local populations and a lack any reward structure for researchers conducting this style of study (see a Framework Forward; Hall, 2009; Hart et al., 2007). For these reasons and more, inviting academic 'outsiders' to partner in ES research may prove to be very difficult for some 'traditional' academics. Yet if the goal is to create usable knowledge that will affect change, it may be the right way forward.

Social Science Barrier 3: A Focus on 'The Individual'

Social scientists who address large scale, diffuse environmental issues, such as climate change, have largely focussed on human agency and lifestyles — what Shove (2010) calls the ABCs- Action, Behaviour, and Choice (see Ajzen, 1991). There has been a paucity of studies which go beyond agency in questioning how socio-political context or government initiatives can powerfully shape public response to environmental threats. Looking at environmental attitudes and behaviours as independent from the places and policies under which they emerge is akin to blaming farmers for a lack of agricultural output in times of drought (Halpern et al., 2004). Whether it is the physical or social, the environmental spaces in which humans live can greatly influence lifestyles and behaviours. As a result of this individual-focused research approach, there has been a limited capacity for social science to drive policy surrounding diffuse environmental issues, including climate change.

Proposed Solutions

In order to advance our understanding of the interaction between human lifestyles and large- scale environmental issues like climate change, social scientists must follow the advice of Shove (2010) and "go beyond the individual". Already there is a growing collection of broadly defined social science research that reveals environmental policy is shaping human and corporate behaviour across multiple categories (Ramkissoon, Smith, & Weiler, 2013; Steg, Bolderdijk, Keizer, & Perlaviciute, 2014). In these types of studies, researchers may often present a more tangible case for policy change, whereby researchers are critical of the context which drives damaging behaviour and not the behaviour itself. Though this type of critical appraisal of the policy systems created or modified by policymakers may be difficult to hear, it is a necessary approach if society is to move beyond current research strategies and develop more policy-impactful research.

An emerging example of research which does "go beyond the individual" in the Canadian context is found within the newly defined 'social acceptance of wind energy' literature. For example, recent research from Ontario, Canada revealed that the politics and implementation of green energy policy driving wind energy development is the major source of public resistance and opposition (Baxter, Morzaria, & Hirsch, 2013; Songsore & Buzzelli, 2015; Walker et al., 2018; Walker, Baxter, & Ouellette, 2014). The enormous power of two components of the green energy development processes: planning procedures and financial compensation increase our "understanding how [development] policies interact with social processes [e.g. support for wind energy] at the local level" (Walker et al., 2014: p. 730). This contrasts early literature that connected wind energy opposition with the 'selfish', 'ignorant', or 'uneducated nature' of rural residents.

A Framework Forward

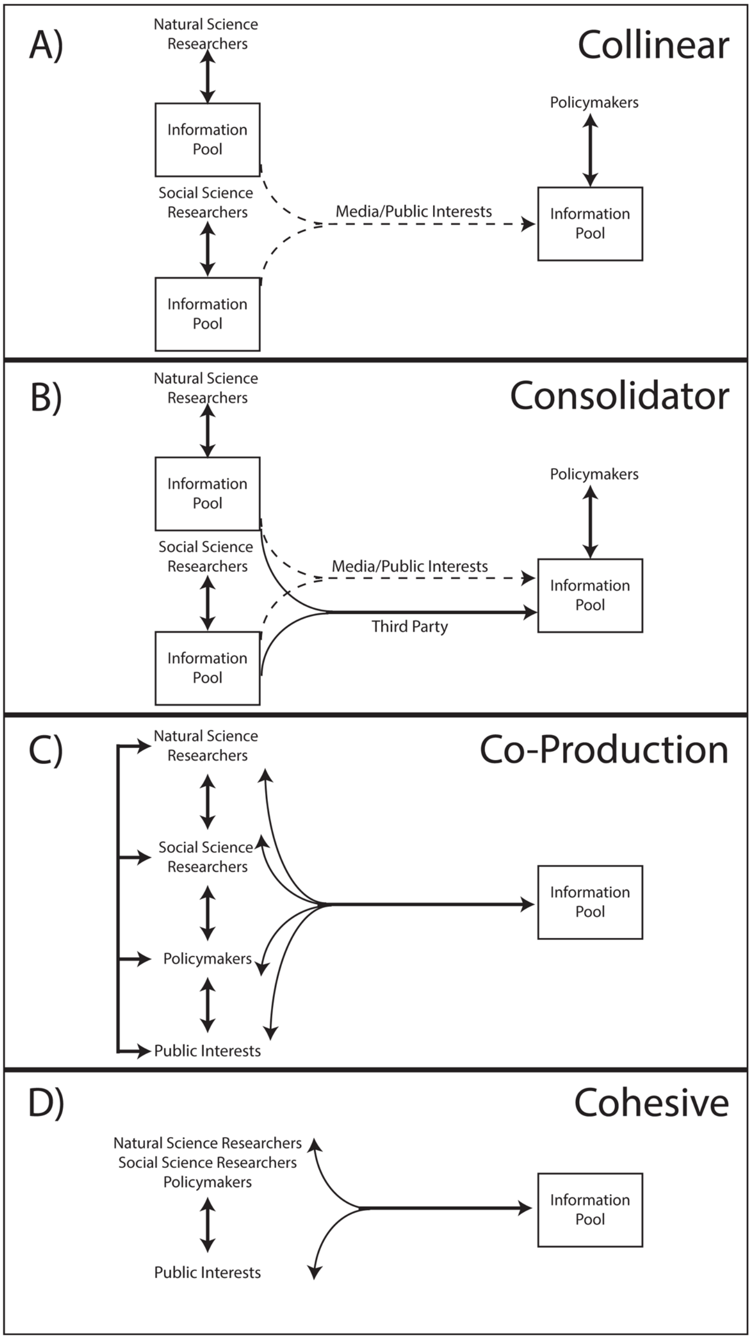
Addressing discipline-specific barriers is necessary to bridge the research-policy gap. That said, such efforts will be most successful if they are scaffolded onto an effective framework that promotes an achievable change in how knowledge is transferred between researchers and policymakers. In the current framework, the majority of new scientific knowledge is produced in isolation of other ES scientific disciplines (ex. natural and social science) and policymakers, often in a *collinear* fashion (Sarkki et al., 2015; Weichselgartner & Kasperson, 2010) (Figure 1A). The authors van Kerkhoff & Lebel (2006) describe this framework as the 'trickle down' approach, where researchers believe high quality knowledge will be actively taken up and translated into action by policymakers and stakeholders. In this framework, ES researchers alone are responsible for identifying core ES problems faced by society, developing an appropriate research program to produce new information needed to address this problem, and interpreting the potential implications of this new knowledge for society (van Kerkhoff & Lebel, 2006). However, once the researcher has published new information their role in transferring knowledge into action is considered complete. It is the role of the end user to find and apply this new knowledge as action, with little opportunity to provide insights backs to the researchers on the ES problem selection, research design, or knowledge interpretation. As such, the collinear framework routinely fails to translate knowledge into action. Scientists are inherently biased towards developing research programs that will advance their own careers, with often limited direct applicability to policymakers and end users (van Kerkhoff & Lebel, 2006).

The academic reward structure is an important but under acknowledged cause of the ES research-policy gap, sustaining the current use of the collinear framework by academics despite its acknowledged flaws. Academia consistently rewards the publication of research as well as grant income over less tangible benefits such as engagement with policymakers and end users (Cook & Odom, 2013; Knight et al., 2008). Hawkins et al. (2015) found little to no relationship between broader community involvement and academic promotion; instead, promotion and tenure were much more affected by overall academic output. Without proper structures in place that reward this type of engagement, time-stressed environmental scientists will find it difficult to prioritize networking with others — including policymakers (Knight et al., 2008).

In figure 1, the first framework, given in (A), is the collinear framework and serves as an example of the research-policy gap, where both researchers and policymakers have functionally independent information pools that they draw from and also contribute to, with minimal transfer between pools. The majority of the transfer that does occur is weak and is mediated by both the media and public interests. It is important to note the policymakers are accessing and applying scientific knowledge, but it tends to be predominantly produced by government research bodies and with only a subset of the wider scientific knowledge produced by the academic community. An observed solution to this gap (B) is the consolidator framework, which is the establishment of a strong information transfer link, mediated by a 'third party' able to interpret primary research into readily accessible terms for policymakers — however, policymakers are not able to provide any feedback directly to the scientific community. The third framework (C) is co-production, which harmonizes the information produced and utilized by researchers, policymakers, and the public into a single pool that is inherently accessible to end users. The final framework (D) is the cohesive framework proposed by the authors, where ES researchers and policymakers form temporally-stable, interdisciplinary teams housed within the same facilities to support the continuous, multi-directional dialogues needed to address the fine-scale ES barriers identified in this chapter, while conducting impactful ES knowledge generation. Similar to the co-production framework, policymakers and researchers still collaborate in an iterative fashion with the public to generate a shared knowledge pool, however, public partners would not necessarily be based out of the same facilities.

To ease the isolation effect between researchers and policymakers, some authors now recommend the involvement of a 'third party', or a *consolidator,* as an improved framework (Dilling & Lemos, 2011; Hering, 2016; Weichselgartner & Kasperson, 2010). The consolidator's role is to identify, coalesce, translate, and transfer ES science into plain language that can be easily taken up and applied by policymakers (van Kerkhoff & Lebel, 2006). Similar to the collinear framework, knowledge production in the consolidator framework is generally one directional (researchers to end users), with little opportunity for policymakers to directly inform research programs (van Kerkhoff & Lebel, 2006). Moreover, no efforts are made to synchronize the energies

Figure 1. Depiction of four different information transfer frameworks between primary researchers and primary policymakers



of ES academic disciplines like natural and social sciences. Instead this framework focuses on building bridges between researchers and policymakers (Figure 1B). Efforts have already been put forth to apply this framework by a variety of third party groups, such as information brokers and invested collaborative organizations, with some success (Dilling & Lemos, 2011; Hering, 2016). These groups, however, are the exception for most knowledge produced and are not the accepted norm. Moreover, it seems unlikely a consolidator framework will become widely adopted as researchers and policymakers report little interest in communicating through a third-party organization (Choi et al., 2016).

A more promising option to close the ES research-policy gap is the establishment of a *co-production* framework, where co-production is "the combination of scientific resources and governance capability that shapes the extent to which a society, at various levels, can operationalize relationships between scientific and public, private, and civil society institutions and actors to effect scientifically-informed social change" (van Kerkhoff & Lebel, 2015 p. 14). More simply put, co-production is the coordinated and synchronized production of new knowledge by experts and relevant stakeholders, including policymakers, with an emphasis on stakeholder interaction, useable science, and interdisciplinarity (Lemos & Morehouse, 2005; Wyborn, 2015). In contrast with the collinear and consolidator frameworks, the co-production framework mandates that knowledge production is non-linear, with stakeholders continually providing formative input throughout the entire knowledge production process (Lemos & Morehouse, 2005; Sarkki et al., 2015). The generated knowledge must be directly applicable to the end users' needs, including supporting policy formation. Finally, the co-production team must be interdisciplinary, working together in an iterative capacity with the same members until an integrative solution is produced and specific knowledge needs are met (Lemos & Morehouse, 2005). By generating new knowledge together, it ensures both ES researchers and policymakers are drawing from the same knowledge pool, effectively removing the research-policy gap (Figure 1C).

As part of the co-production framework, natural and social science academics should take a leadership role by applying interdisciplinary approaches in their own research programs. By doing so academics involve a range of experts needed to fully address the multi-faceted nature of many ES issues, while improving effective communication across their respective disciplines (Weichselgartner & Kasperson, 2010). In her description of what she calls actionable socio-environmental science, Palmer (2012) notes that scholars must go beyond their "collaborative comfort zone[s]" (p. 5) and engage in collaboration between the natural and social sciences. By applying this research model, academics are forced to produce publications understandable to all fields of study involved — often increasing the readability of the product to a wider audience. That said, the call for interdisciplinary research programs does not mean the end of the classical, discipline-based expertise so familiar in academia (Lemos & Morehouse, 2005). As Holm et al. (2013) describes using the analogy of sports, the best teams are usually made up of exceptional, yet specialized individuals. Just as "a striker on a football (soccer) team would not have the same success as a defender" (p. 32), a successful collaborative research team requires a variety of academic partners, each with their own set of skills, knowledge, and expertise.

Many science-policy interface organizations constitute a successful actualization of the co-production framework (Wesselink, Buchanan, Georgiadou, & Turnhout, 2013). SPIs can include any "organizations, initiatives or projects that work at the boundary of science, policy and society to enrich decision making" (Sarkki et al., 2015 p. 502-506), and are generally optimized when they are perceived as credible, relevant, and legitimate (Cash et al., 2003). Broadly, they facilitate an iterative, multidirectional dialogue between researchers, policymakers, and the public to stimulate real change in society (Sarkki et al., 2015). These organizations can have many labels including the aforementioned Community-Campus Partnerships, Participatory Action Research groups, and Community-Based Participatory Research groups as well as Global Environmental Assessment groups (GEAs). Global environmental assessments are considered a particularly successful type of SPI and form of co-production, consistently transferring knowledge into action because of government buy-in and novel interdisciplinary synthesis products (Kowarsch et al., 2017). Specifically, GEAs are defined as "largescale, highly deliberative processes where experts are convened to distill, synthesize, interpret and organize existing scientific knowledge (on environmental issues) to inform decision-making" (Jabbour & Flachsland, 2017 p. 193). Particularly successful examples include the intergovernmental panel on climate change (IPCC) and the fifth Global Environmental Outlook (GEO-5) assessment, accredited with catalyzing the Paris Agreement and influencing the 2030 Development Agenda respectively (Kowarsch et al., 2017). Accordingly, some consider GEAs like the IPCC to be a model application of the co-production framework that when scaled appropriately, can serve as an ideal archetype for future co-production efforts.

While co-production is a laudable framework, it generally fails to address many of the key fine-scale barriers limiting natural and social science translation into policy, as identified above. Accordingly, the authors present the *cohesive* framework, which fully integrates new knowledge production with policy formation at leading academic centers, such as universities. In this framework, temporally-stable, interdisciplinary teams of ES researchers and relevant policymakers work within the same facilities (Figure 1D). This allows for a *continuous*, *low-latency*, sustained, and multidirectional dialogue between all parties. Policymakers can directly inform research programs, while scientists can personally resolve issues of data complexity and uncertainty, perceptions of limited negative impact of ES issues on broader society, and advocate for improved natural science literacy and social science funding where appropriate. The authors are not proposing all ES policymakers be relocated to academic centers, but a subset of ambassadors should be strategically positioned at centers of ES research excellence across the country. In this framework researchers and policymakers still work in an iterative fashion in concert with the public to enact real change in society, but the interface between researchers and policymakers is strengthened and enriched. The cohesive framework inherently retains the key characteristics of the co-production model required to successfully develop new knowledge; however, it also creates a unique platform for multilateral political and scientific advocacy amongst partners. That said, cohesive knowledge production would not universally replace co-production efforts, but instead should be applied in a synchronous, network style approach to maximize research-to-policy efforts and efficacy.

The cohesive framework could theoretically take many potential physical forms, but the Institute for Watershed Science at Trent University, Peterborough, Canada provides an excellent example of a long-term, cohesive partnership between ES academics and government bodies within one facility (http://www.trentu.ca/iws/overview.php). This collaboration has the specific commitment to "conduct peer-reviewed, multi-disciplinary science" (Institute for Watershed Science, 2017). Over the past 26 years the institute has created an environment where government employees and academics work side-by-side producing over 20 successful research programs, numerous peer-reviewed publications, as well as policy-targeted new knowledge.

CONCLUSION

For society to be responsive and adaptive to the growing number of ecological crises that it faces, the ES research-policy gap must be minimized, if not closed. The researchers and policymakers working within the ES field are acutely aware of this great need, but also of the complexity, in closing the gap. As ES research is often inherently multi-disciplinary, researchers from different 'academic silos' often struggle to communicate with each other, further impeding their capacity to communicate with citizens and policymakers. The situation is further complicated by the unique research-policy barriers that core ES academic disciplines face. The main barriers and solutions applicable to the natural sciences are not shared by the social sciences. In the natural sciences researchers consistently struggle to communicate the importance and complex nuances of their research and the ES issues at hand to the general public and policymakers alike. Social science researchers, conversely, often lack the necessary funding to pursue ES inquiry, perhaps as a consequence of a history of less-applied study focused on the actions of the individual. Still, none of these barriers should be viewed as insurmountable. Many of these barriers can be addressed by researchers themselves if they adopt slightly modified practices, such as searching out non-traditional funding sources, or targeting empirical research programs to quantify the local impacts of an environmental issue. That said, shifting new knowledge production away from the traditional collinear framework could have truly transformative impacts on the research-policy gap. By adopting the co-production framework researchers and policymakers can work together to identify, study, and address key ES issues for society. By implementing the cohesive framework researchers and policymakers will be able to directly resolve fine-scale research-policy barriers, while still working in an iterative fashion with the public to generate new knowledge. Only by transitioning away from the collinear framework and tackling core research-policy barriers will policymakers see more on-demand, policy-poignant knowledge, while academics see a better application of their research. Such a seamless research-policy relationship is no doubt required if we are to ensure a stable, safe, and healthy environment for future generations.

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KEY TERMS AND DEFINITIONS

Co-Production: The production of new knowledge by an interdisciplinarity team, involving end users in a multi-direction dialogue throughout the production processes to generate usable knowledge.

Cohesive Production: The production of new knowledge by a temporally-stable, interdisciplinary team of researchers and policymakers housed within the same academic facilities, able to conduct continuous, low latency, and multidirectional dialogues to resolve fine-scale research-policy barriers, while still working in an iterative fashion with the public.

Collinear Production: New knowledge production and dissemination conducted primarily by research experts, with limited input or feedback from end users on the utility or quality of the final product.

Consolidator Production: A one directional transference of research products to end users via a third-party organization that coalesces and translates useful new knowledge into a readily accessible format for end users.

Environment and Sustainability Research: New knowledge production on the functionality of our past and current socio-ecological systems, as well as the development of improved future systems.

Knowledge to Action: The transference of new knowledge into impactful societal change.

Research-Policy Gap: The limited integration of available research into policy.

Chapter 9
Planning Urban Futures With Reference to Sustainable Cities

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ABSTRACT

This chapter is a review of scholarly works on planning for urban futures with special reference to sustainable cities. The chapter aims to produce an update of the challenges and current perspectives on urban planning, sustainability and development across the globe. As informed by research from the academic and scientific communities, the review provides the prospective directions and trends for securing a sustainable urban future. In the sustainable cities discourse, recent intellectual inquiry focused on the conceptualization and knowledge production to create sustainable cities. Though the scope of the review may not be exhaustive, the purpose is to articulate the current progress in the research front concerning concepts and definitions on sustainable cities, planning and methods for urban sustainability development and assessment. The ultimate goal is to provide local authorities, practitioners and/or city governments with some perspective and guidance in working towards urban sustainability in the future.

INTRODUCTION

Over the last few decades, sustainability research has grown significantly with the surge of academic publications about Sustainability Science as a new field of research and practice that has emerged on a global scale (Shahadu, 2016; Bettencourt & Kaur, 2011; Kates, 2011; Kates, Clark, Corell, & Hall, 2001). Since the 1980s, the new science has been viewed to require more vigorous academic attention as a

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distinct discipline on sustainability (Shahadu, 2016). Different from the paradigm of sustainable development (SD), 'sustainability' has been taken as a planning concept with its beginnings in ecological thinking and economics and now widely applied to studies in urban development (Adinyira, Oteng-Seifah, & Adjei-Kumi, 2007). There are various conceptualizations and diverse interpretations of 'sustainability' as a concept, paradigm or buzzword, as others put it. Some use 'sustainability' interchangeably to mean sustainable development but in theory, they are different.

Historically, sustainable development has been the subject of many debates since it emerged and came into use in policy circles more than three decades ago and labeled either as an 'oxymoron', a contradiction of terms, or just another jargon deemed to be overworked, if not overexposed (Robertson, 2014; Du Pisani, 2006; Redclift, 2005; Beekerman, 1994; Daly, 1990; WCED, 1987). Regardless of what the critics say about sustainable development, it is contested yet recognized worldwide as a driving force in development discourses, if not in the broader policy arena. Comparatively, the concept of sustainability as a normative notion suggests how humans should act towards nature and be responsible towards one another at the present as well as the future generations (Baumgartner & Quaas, 2010). Others stressed the meaning of sustainability *per se* varies according to context and perspective (Brown, 1987; Shearman, 1990). In the past, environmental problems such as deforestation, salinization and loss of soil fertility that occurred as early as the ancient Egyptian, Mesopotamian, Greek and Roman civilizations are also among the pressing environmental issues that beset us in the past and current century (du Pisani, 2006). Historian du Pisani (2006) pointed out that the term 'sustainability' was first used in German Forestry circles by Hans Carl von Carlowitz in 1713 to call for a balance of harvesting old trees and have enough young trees to replace them. Here, the purpose is not to establish a precise, or universal definition of the term 'sustainability' as there are multiple versions and differentiated meanings, as informed by varied research agenda. Two widely articulated views of sustainability pertain to a) the triple bottom line or three pillars based on environmental, economic and social dimensions; and b) the need to maintain equity between current and future generations (Mori & Christodoulou, 2012; Shahadu, 2016; Turvey, 2017). In understanding sustainability as it reflects itself in an urban context, scholars believe that humanity has the ability to build a sustainable world through the practice of urban sustainability (Smith, 2015; Glaeser, 2011; Owen, 2010). While there exists a broad literature on 'sustainability', the academic focus on the theory and practice of urban sustainability that concerns 'sustainable cities', have yet to gain robust attention from the community of intellectual and scientific scholars to address the challenges of the concepts and processes in sustainable urban development.

Sustainable urban development is currently the top priority of cities in both the developed and developing countries (Mori & Christodulou, 2011; Ben-Zadok, 2009; Keivani, 2009; Williams, 2009). This is triggered by the unprecedented 21st century issues of environmental sustainability, as well as the political, economic and cultural challenges of rapid urbanization that significantly affected progress in urban theory and practice (Pizarro, 2015; Banai & Rapino, 2009; Whitehead, 2003). Since the 20th century, the world's staggering urban population has posed various concerns to planning for sustainable urban development. With more than half of the seven billion people living in towns and cities on Earth, the 21st century is described the 'century of urbanization' (United Nations, 2008; Keivani, 2009). Based on global statistics, 54 per cent of the world's population in 2014 is urban, and the future of humanity is absolutely, urban (McLaren & Agyeman, 2015; WUP, 2014). The current global urban population is expected to rise by more than two thirds in just three decades. Approximately six billion of the world's nine billion people will live in urban settings by 2050 (Smith, 2015; WUP, 2014; UN, 2011; Bos, Vu, Masiah & Bulatao, 1994). Close to one third of urban dwellers in North America live in settlements with fewer than 500,000 people. In Canada, urban population was 82% in 2014, and projected to rise to 88% by 2050 (WUP, 2014). With the huge volume of urban dwellers, planning for cities is beset with many environmental, economic and social problems in terms of sustainable urbanism (Williams, 2009; Keivani, 2009; Yigicanlar & Dizdaroglu, 2015).

The pattern of urbanization since the 20th century showed that demographic changes and/or increases were found mostly in cities of the developing world. Though one way to look at urban change where there is population growth is to assume that many countries will urbanize far into the future, there are some countries that may not grow economically hence the need to take the world's urban growth statistics with some caution (Satterhwaite, 2016). There are low-income countries with serious economic growth problems and political instability or even civil war that may certainly face smaller and slower growth in their urban populations given their hardly encouraging situations. At the heart of the sustainability discourse is the emphasis upon the prudent use of environmental resources and social equity considerations, and the call for a more effective and resilient planning and development perspective (Yigitcanlar & Dizdaroglu, 2015; Yigitcanlar & Kamruzzaman, 2015). Since urban settlements are now the world's dominant human habitat, city sustainability as a compelling imperative is an obvious development goal. In confronting the enormous transformation of cities, societies and the environment, sustainable urban development is invariably the contemporary approach towards building a desirable future.

This Chapter reviews the literature on the challenges that relate to planning urban futures as it relates to 'sustainable cities' across the globe. It attempts to highlight important scholarly works about the prospective research directions and trends in securing a sustainable urban future for tomorrow, today. Within the sustainable cities discourse, there are increasing efforts in intellectual inquiry that seek the conceptualization, analysis and knowledge production in hopes to create sustainable cities. In this review, conceptual and procedural challenges are identified to understand the progress and developments that relate to the narrative of sustainable cities. The goal is to be able to provide local authorities, practitioners and governments with some perspective and guidance in working towards future urban sustainability.

BACKGROUND

Historically, cities are referred to as urban areas which are defined by settlements of larger population size and marked by high densities within areas distinct from those surrounding it (Kaplan, Wheeler & Holloway, 2009). As a recent phenomenon, the evolution of cities date back more than 6,000 years ago at the earliest and globally by around 300 years (Kaplan et al., 2009). A city is typically an urban place that is non-rural, non-agricultural and functions as a centre of political, economic power, technological innovation, artistic achievement and much more (Fouberg, Murphy & de Blij, 2015). For cities to form, Kaplan et al. (2009) cited three preconditions to be in place, namely: ecological settings, technology and social organisation. Given these pre-conditions, most early cities developed in sub-tropical regions, river banks, and in proximity to fertile soil, fresh water and physical resources. Though some cities of the world recurrently experience boom and doom, cities commonly play a diversity of functions serving urban populations and operate as complex systems often described as growth machines; anchors of modern culture; centers of interaction and specialization and agents of societal change (Fouberg et al., 2015; Khakee, 2014; Kaplan et al., 2009). There are assertions of cities as 'growth machines' analyzed in relation to carrying capacity and ecological footprint as populations physically occupy substantial spaces in an urban area (Khakee, 2014). The enormous demographic size of urban areas had in fact placed tremendous challenges to the consumption of energy, water, nature and materials and provision of public services and amenities costs. In essence, cities provide local services such as water, sewage and waste services, development charges and utilities, public transit, land use planning, infrastructure and economic development (Madsen, 2004). At the center of debates are also questions on urban governance with respect to their operation, given its constant concern to maintain the well-being of its residents or over-all management of life in urban areas while sorting out the day-to-day urban management issues of city life. Another concern about cities that has been identified in the Brundtland (WCED) 1987 report is centered on the environmental problems that have a local source or origin. This reality comes to fore as the urban dimensions of sustainability are increasingly getting more attention on a local, regional as well as global scale. But first is a review of cities in theoretical terms.

Cities in Theory

In the face of the complexity and dynamics of the city, the literature points to a multiplicity of urban theories or 'theoretical pluralism' with no dominant perspective being privileged to be a monopoly in urban matters or to explain the urban form and function. This means that with the complexity of urban form and function, there is no single philosophy or meta-urban theory that dominates the literature. A theoretical review of the city shows several types of urban theory. The normative theory of the city is focused on the human purposeful activities and city form as its principal feature. An example is the 'good city form' well known as the best example of the normative theory of the city, is well-fitted, stable and resilient… accessible and well controlled (Lynch, 1981, p. 235). A functional theory of the city is 'honeycombed with values', with examples of values as sustainability, social justice and efficiency (Farr, 2008). The economic theory of the city has increasingly become accountable to the space-economic impact of innovations and global trade (Krugman, 1995).

In their progress review of urban theory, Banai and Rapino (2009) examined the historical theory, the ecological theory, the economic theory, the communication theory, and the historical and material theory of the city. They argued that the urban theory is fragmented since the city's complexity defies a unitary imagery, though not necessarily a weakness in theoretical sense. Using Lynch's (1981) encyclopedic review of the city, its conceptualization is reflective of the changing spatial, demographic and socio-economic and technological environments of the times. In the ecological theory of the city, the planning and design of sustainable cities increasingly treated nature and the built environment as integrated elements of an evolving ecology. It was noted in the review that the 'sustainable city' is making room for a multicultural, diverse demography across the globe. At the same time, the quest for justice and fairness continues in the sustainable city (Banai & Rapino, 2009). Research indicates that planning for the sprawling urban population is of utmost importance that the idea of sustainable urban development does not come without challenges (Keivani, 2010; Williams, 2010). Practitioners and academics are mutually interested in finding out the most appropriate urban planning design particularly the one which relate to the creation of a 'sustainable city' of which definition is diverse as the idea of 'sustainability'. In designing the beautiful city, the Garden city, or the Eco-city, planners and planning-related professions have been in search of ways to create sustainable ways to develop urban areas.

Urban Planning and Design of Cities

Tracing the past substantive contributions to the field, planning visionaries such as Patrick Geddes, Lewis Mumford and Jane Jacobs have shown interest to develop designs and planning techniques to build sustainable urban environments (Smith, 2015; Wheeler, 2000; Jacobs, 1961). In tracking the early forms of sustainable communities, Hempel's (1999) work in Mazmanian and Kraft's edited collection is highlighted. The term 'sustainable communities' refers to those communities that are planned, built or modified for sustainable living and characterized by attributes of social sustainability, economic sustainability and environmental sustainability. From both development and environmental lens, there are early forms of sustainable communities that are labeled in the literature as 'sustainable cities', 'green cities', 'eco-cities', 'livable cities' and 'livable communities.' The edited collection by Mazmanian and Kraft entitled: *Toward Sustainable Communities: Transition and Transformation in Environmental Policy*, has contributed to better understanding about cases and applications in the field of *community sustainability* as the world transitions toward a sustainability-based environmental policy in the 20th century. The book argued that it was not essential to have a single definition of environmental sustainability, SD or sustainable communities to study the transitions in public policy. It has acknowledged the groundwork that was laid out by Patrick Geddes (author, *Cities in Evolution*, 1915) and Lewis Mumford, author of *Sticks and Stones* (1924) and *The Golden Day* (1926).

Geddes stressed the integration of environmental protection and social organization in urban design. Geddes believed 'the corrosive effects of industrialization on geographic community with swift exhaustion of material resources' was a bit too much. Mumford was a leader of the Regional Planning Association during the 1920s in the US. He was concerned with the early attempts to address the social and environmental consequences of the loss of community in his so-called 'machine civilization' during the industrial age. He portrayed colonial New England as a promising model for contemporary human settlements, encouraged community and admired town planning as a culture of community with a commonality based on civic mindedness and social cohesion. Mumford believed in two things- the first is the attainment of a genuine 'sense of place' grounded in nature parallels that encourage community and a productive, equitable and social cohesion of the built and natural environments. The other is the 'sense of commons' defined by Mumford as an acceptance of common destiny and social relations based on dignity and mutual respect (Hempel, (1999). Mumford's work was known to reconstruct the 'communitarian social tradition' that was deemed appropriate for the 20th century (Hempel, 1999, p. 49). In the same edited book, Lamont C. Hempel's (1999) Chapter on the *Conceptual and Analytical Challenges in Building Sustainable Communities* is relevant in tracing early types of sustainable communities. The work pointed out the intellectual origins of the concept of sustainability and the competing orientations still found today in communities and cities in North America and others. Hempel's Chapter provided a snapshot of the field applications of the 'sustainable communities' movement over the last three decades as countries like the US must come to terms to address the challenge of environmental sustainability. In listing some contributions on the evolution of the sustainable community framework since the 18th Century, Hempel included the Garden City movement (Ebenezer Howard, 1898); bioregional planning and design (Patrick Geddes, 1915); the American New Towns movement; and grassroots communitarian movements (1940s). The Garden city movement is a planned settlement conceptualized by Howard (1850-1928) offered the benefits of urban living away from crowding and squalor of Victorian cities. This city offered urban living away from crowding and squalor of Victorian cities. It promoted the use of the greenbelt with a low housing density, parks and open spaces and plentiful allotment of urban areas as a reaction to the ills of the industrial revolution by providing greenery for urban dwellers (Smith, 2015). The bioregional planning and design idea by Geddes has argued that to be effective, the design is interdisciplinary in approach and focused on building sustainable communities as adopted by the University of Idaho.

The American New Towns Movement involved newly created green field sites around a pre-existing settlement. It was planned to relieve overcrowding and congestion in the major conurbations with the aim to create a town that would be economically viable with light industry, shops and services. In the UK, a New Towns Act passed in 1946 aspired for low housing density (five houses per hectare) and neighborhoods of 5,000 people with their own shops, schools and health centers. In the 1960s, the models and ideas included the great society urban programs; the decline of faith in technological progress; and the Spaceship Earth idea (Fuller, 1969). The concept of Spaceship Earth was a view of the world and an expression of concern over the use of limited resources available on Earth and considered human behavior where it asserted the need for harmony toward working for the greater good. To this day, this idea has become an iconic and symbolic structure that soon became a part of the corporate feature of the Walt Disney World Resort.

In the 1970s, more outstanding ideas came into surface and were subject to debate and discourses such as *Limits to Growth* by Meadows et al, 1972; resilience of ecological communities (Holling, 1973), local self-reliance and appropriate technology movements in the 1970s (e.g., Morris, 1982); *Urban ecology and Eco-city movement* (1987) and strategic coupling of the environment and development within the sustainable development dialogue in 1987 and 1990s (Hempel, 1999). Holling's *Resilience Ecological Communities* meant communities able to bounce back or recover through an adaptation; or those with the capacity for returning quickly to their previous state to a constancy of persistence. These communities are capable of being back where they were, actively influencing and preparing for economic, social and environmental change. *Urban ecology and Eco-city movement* surfaced in 1987 with the strategic coupling of the environment and development within the sustainable development dialogue in 1987 and 1990s (Hempel, 1999). The '*Urban ecology and Eco-city movement*' (Engwicht, 1993) placed emphasis on urban ecology which is a sub-field of ecology that deals with the study of organisms in an urban or urbanized community and their interactions. Here, urban ecologists studied trees, rivers and open spaces and examined how these resources are affected by pollution, overdevelopment and pressures. The Eco-city movement was first launched in the 1990s with the vision for an ecologically efficient industry integrated with the people's needs and aspirations. With the Eco-city seen as an ecologically healthy city, this movement was characterized by a harmonious culture and landscapes where nature, agriculture and the built-environment were functionally integrated in a healthy way. Clearly, what is needed is a research on the translation of sustainability concepts into planning and how these could lead towards building sustainable cities. Such research is expected to provide insights into the relationship between the urban issues, priorities and strategies in the pursuit of urban development and sustainability of cities, broadly defined.

UNDERSTANDING URBAN SUSTAINABILITY

The terms *urban sustainability* and *sustainable urban development* are closely related and used interchangeably to mean the preferable conditions within an urban area (Hassan & Lee, 2015). To Wheeler (1996), 'sustainable urban development' aims to create cities and towns that improve the long-term health of the planet's human and ecological systems (p. 55). Maclaren (1996) defines sustainable *urban development* to refer to the strategies and processes toward sustainability. Also associated with this term is sustainable urbanization which refers to local and global sustainability (Roy, 2009; Hassan & Lee, 2015). For *urban sustainability*, it is characterized by desirable urban conditions that concern intergenerational and intragenerational equity, environmental protection, economic vitality and minimal use of non-renewable resources and people's well-being (Adinyira et al., 2007). The term 'urban sustainability' is seen as a more appropriate vehicle for addressing sustainability issues relative to cities and planning. An essential view of *urban sustainability* pertains to it as a place-dependent notion suggesting that problems between places vary and as such, we cannot generalize their situations from one place with another (Pow & Neo, 2013). There are a number of definitions of 'urban sustainability' in the literature (Turvey, 2017; James, 2015; Tomalty, 2013; Adinyira et al., 2007) In this Chapter, 'urban sustainability' is an idea of urbanized towns and cities organized without an excessive reliance on the surrounding hinterland and characterized with livable spaces, prosperous economies, secure environment and empowered communities (Turvey, 2017).

In looking at planning's more contemporary attempts to develop sustainable urban communities given the growth of urban populations, cities faced the issue of urban sprawl as a phenomenon tied to the automobile era with significant waste of farmland. The term 'sprawl' is attributed to urban growth with low population density, leapfrogging, separate land uses and dependency on the car or transportation (Fischler & Wolfe, 2006). Urban sprawl which are urban areas found in many growing cities around the world characterized by an unrestricted growth of housing, commercial developments and road networks over large expanses of land (Fouberg et al., 2015). Urban planners and developers argue that urban sprawl has little concern for urban planning. In the 1980s, New Urbanism was introduced as a "complex planning paradigm and social movement that has recently become influential in planning, residential development and government housing (Al-Hindi & Till, 2001, p.189). In 1993, the Congress for New Urbanism, presented the world with an urban design philosophy for urban revitalization, development and suburban reforms with walkable neighborhoods and a diversity of housing. As pursued by planners, the rationale in the design was to reduce people's time in traffic, emphasize pedestrian scale and mixed-use spaces, offer a supply of affordable housing and address the challenges of urban sprawl (Fouberg et al., 2015; Kaplan et al., 2009). Ideally, it seeks more environmentally, ecologically, economically and socially sustainable communities, livable neighborhoods, really in urban and suburban utopia (Al-Hindi & Till, 2001). New urbanists wanted to promote a sense of community and a sense of place in their vision of urban design that supported regional planning of open space, right architecture and appropriate planning. The only problem is that it exists in relatively few neighborhoods despite its appeal in urban development.

Also taking on a regional approach like New Urbanism is the movement for transit-oriented development (TOD) (Calthorpe, 1993). TOD links land se planning and urban design along with transportation planning to create higher density, nucleated urban clusters in mass-transit stops (Fischler & Wolfe, 2006). The most cited example of a TOD is the Town of Mount-Royal, an inner suburb of Montreal, Canada. A more comprehensive approach to containing urban sprawl is that of the Smart Growth movement (Bunting & Filion, 2003; Onyschuk, Kovacevic, & Nikolakakos, 2001). Like other planning designs, critics for 'Smart Growth argue that is vague enough in using it as an intervention in urban change. The approach is purportedly meant for planning, regulation and construction relative to land, natural resources and public funds to promote greater densities and prevent leapfrog development, in-fill development and reuse of brownfield sites among others. Advocates of smart growth assert that before new public investments are made, existing investments must have been fully exploited by infill development (Fischler & Wolfe, 2006). Existing areas and new suburbs are among those targeted for smart growth projects for such purposes as residential densification and making the urbanized area more attractive to new residents.

Yet another approach is 'Smart Growth' as explored by planners in the United States and seen as a 'better way to build and maintain towns and cities (Smith, 2015). The design means building urban, suburban and rural communities near jobs, shops and schools; supports local economies and protects the environment. The Smart Growth Network had adopted guiding principles such as mix land uses, walkable neighborhoods, compact building design, variety of transportation choices to name a few. In the review of this design, authors cited some problems associated with Smart Growth such as having more regulations, more congestion and less affordability in housing (Downs, 2005; Nelson & Wachter, 2003; Alexander & Tomalty, 2002). Opponents of Smart Growth argue that the lack of design guidelines limits its success and that the political and urban geography of most of the US do not make it a suitable strategy for implementation. According to Smith (2015), Smart Growth is an ideology that is bigger than a single city but smaller than a state in its application.

DEFINING 'SUSTAINABLE CITIES'

Here, a review of existing definitions of a 'sustainable city' is made briefly to trace how it has evolved over time with differentiated connotations and meanings. An obvious finding in the review is that the meanings of the term is as diverse as that of sustainability in current literature. For instance, the notion of the sustainable city is said to have emerged as a political initiative to respond to urban environmental degradation in the twentieth century (Hassan & Lee, 2015). In the late 1970s, the efforts for planning and management of human settlements were associated with addressing issues that concerned urban and rural communities which were allied with sustainability questions at the local level (White & Lee, 2009). To others, a sustainable city is framed as a 'city that meets the social, cultural, environmental, political, economic and physical objectives where there is equitable access to all services (Rogers, 1997). There is no shortage of cutting-edge types of cities that have been examined widely in the literature from the compact city to ubiquitous city, also called the U-city (Yigitcanlar & Lee, 2013; Hassan & Lee, 2015). The U-city in countries like Korea features ICTs in the city infrastructure and eco-technologies to provide residents with quality environmental resources, conserve energy and water supply (Yigitcanlar & Lee, 2013). Dantzig and Saaty's compact city has a minimum density of 40-80 residential units per net hectare with a height of two to four storeys for more efficiency and interaction. In theory, the compact city does not consider the shortages of livable environments and why suburbs grow outside of the city. More importantly residents wanted to leave the high-density zones for lower-density zones with cleaner environment in a compact city (Hassan & Lee, 2015; Howley, Scott, & Redmond, 2009). With several definitions for the 'sustainable city' label, there are advocates for a city of transition into sustainability rather than the 'sustainable city'. Further, the application of cutting-edge technologies and brandable terminologies of new cities are however deemed to be insufficient to develop sustainable cities (Hassan & Lee, 2015).

While the sustainable city is arguably seen to require resilient and efficient economic, environmental and social systems, others articulate the design of future cities offering the opportunity for the happiness of its residents. In such condition, are sustainable cities "happy" cities? (Cloutier, Larson & Jambeck, 2014). In examining the relationships of four indices of sustainable urban development and the happiness of residents in US cities, Cloutier et al., findings indicated that happiness and sustainable development were positively associated. This refers to the city-level self-reported happiness in US urban areas and noted to be an interesting area for future inquiry in the study of how cities and its components influence happiness and drive the progress toward urban sustainability. In tracing the earlier versions of 'sustainable cities', relevant examples have already been cited before this section, with the discussion of the Garden City movement in the 18th Century developed by Ebenezer Howard (1902), the American New Towns movement and the Eco-city. The Garden City marked the emergence of 'sustainability' as a new paradigm that might reshape the planning profession (Ben-Zadok, 2009). In research and practice, a 'sustainable city' is defined environmentally when resources are used efficiently; when social equity is considered in policy decisions; or when a *compact form* of urban design is adopted in terms of sustainable urban form. For a city to be sustainable, they must recognize the finite nature of the natural resources from which urban activities depend and meet the needs of all people not only of the present but also the future generations (Alberti, 1996). The need for sustainability in cities, coupled with the lack of knowledge on how to deliver it, are important subjects of inquiry in building 'sustainable cities'. Sustainable urbanization requires that cities should generate better income and job opportunities, provide the needed infrastructure for water and sanitation, energy and transportation and preserve its natural assets.

Over the past three decades, 'sustainable cities' have been the leading global paradigm of urban development (Whitehead, 2003; Williams, 2009). There is reference in published works that the 'sustainable city' discourse is now relatively mature, with precise but contested, conceptualizations (Williams, 2009) while others note the paradox of the sustainable city in terms of its meanings and contradictions (Hassan & Lee, 2015). Examples of the latter types of cities labeled as the 'sustainable city' were subject of studies within the sustainability discourse. Hassan and Lee's (2015) study in particular examined three emerging models namely the zero-carbon city, the ubiquitous eco-city (or U-ecocity) and the compact city regarded as an outmoded model. By design, the ubiquitous city is a built environment with information and communication technologies embedded in its infrastructure for purposes ranging from disaster management to pollution monitoring and energy conservation to improve the economic and environmental aspects of the city. In their review, a sustainable city was described to be a self-sufficient city; a political initiative to address urban environmental degradation; a city able to retain the supply of natural resources while achieving economic, physical and social progress.

Dantzig and Saaty (1973) coined the term compact city as a backlash against postwar urban planning was a city with minimum density in urban form; multifunctional in land use; built as nodes in its residential development; and in harmony between spatial structure and the public transit system. Its key feature is to shorten the trip and adopt mixed use in urban patterns. Critics criticized the compact city because it does not consider for instance the shortages of livable environments and the need for green spaces within the city that others in high-density zones left in favour of lower density zones. This city type claimed that a) telecommunication cannot be substituted for social interaction, b) the cost of infrastructure is prohibitive and cannot be affordable to all social classes, and c) profits are gained by the private sector but not by the public sector and its citizens.

The zero-carbon ecocity coined by Richard Register in 1987 in his book "Eco-city Berkely: Building cities for a healthy future" aimed to reduce the emissions of carbon dioxide or green house gases (GHG) to zero (Kolte, Kandya, Lakhtaria et al., 2013). Viewed to contribute to improving the quality of life, the Masdar City in the United Arab Emirates (UAE), the Petite Riviere in Canada, and Barangaroo in Australia among the few models of eco-cities in the world (Elchalakani, Aly, & AbuAisheh, 2013; Reiche, 2010). To Yigitcanlar and Lee (2013), the obstacles to the free carbon city pinpoint uncertainties to waste-free cities and the question of an affordable and sustainable city without getting rid of the car in existing cities. The authors argued that there is an ambiguity of the sustainability notion on 'the impetus to create sustainable cities. They conclude that the use of the label called 'sustainable city' limits the potential for sustainability in future projects and preferred the term "transition toward the sustainable city" as being more accurate and effective. With differing visions of urban futures and a multiplicity of socially constructed views in sustainable urbanism, Guy and Marvin (1999) explains this is due to a diverse and expanded group of interests and competing visions of what a 'sustainable city' is. The need for achieving sustainability in urban areas, and the importance of knowledge on how to deliver it are challenges and opportunities for research and planning when cities define their vision and strategies for the future

(Pizarro, 2015). The urgent need is for concrete urban solutions based on prescriptive policies and knowledge to address the question of 'know-how' that translate urban sustainability into reality at the local city level.

CHALLENGES IN RESEARCHING 'SUSTAINABLE CITIES'

This section outlines the challenges in researching sustainable cities. It summarizes threads of discourse concerning urban sustainability, planning and sustainable urbanism research on sustainable cities. The purpose is to highlight scholarly works to show several attempts to urban planning and design and create an understanding of the latest progress in sustainable urban development. In this intellectual inquiry, the objective is to get perspectives on the research directions and emerging trends that relate to building of sustainable cities.

Challenge of Sustainability, Sustainable Planning and Urban Design Solutions

To achieve a harmonious balance as a global goal in sustainable development, the Brundtland Report in 1987 identified three components of urban development namely: social welfare, economic development and environmental protection (Smith, 1995; Yigitcanlar & Dizdaroglu, 2015). The common assessment points to the complex and destructive impacts of human activities and population pressure on questions of the sustainability of resources and degradation of the environment (Yigitcanlar & Dizdaroglu, 2015). The wide assertion in recent years point to how cities struggle in dealing with local and global environmental issues such as urban sprawl, rapid urbanization, urban population pressure, degraded water quality, air pollution and soil erosion (Parmesan et al., 2013; Mahbub, Goonetilleke, Ayoko, Egodawatta & Yigitcanlar, 2011; Teriman, Yigicanlar, & Mayere, 2009; Pittock, 2003). The response from scholars and practitioners is to frame sustainable planning and design solutions (Yigitcanlar & Dizdaroglu, 2015). Specifically, in developing built environments, Birkeland (2008) stated that the design of cities, buildings, landscapes and infrastructure toward healthy ecological conditions could lead to better life support services, and reversal of impacts on the quality of life for all. In seeking sustainable urban design solutions, several scholars have invariably stated the demographic picture of city life that calls for re-examining the processes and methods to deal with the sheer volume of people in urban areas particularly in megacities in the world (Smith, 2015; Rana, 2011; Keivani, 2009). Others have stressed the need to focus on urban sustainability from a variety of disciplines (Smith, 2015; Wu, 2010; Lake & Hanson, 2000).

Over the last few decades, potential urban planning solutions ranged from Green Building, to Smart Growth and New Urbanism (Smith, 2015). In recent times, an approach to push for sustainable urban places is called the Leadership in Energy and Environmental Design (LEED). In drawing from the foundations laid out by Green Building and others, Smith (2015) sees LEED as an effort to bring the best parts of related urban models toward a more sustainable pattern of development. In promoting sustainable urbanism, it is regarded a tool to reduce urban sprawl and deal with urban regeneration efforts in the US. Green building seeks to construct efficient homes, businesses and facilities to deal with the impacts of new buildings. According to Smith (2015), Green Building have some issues of affordability due to cost of building them and does not allow economies of scale for some larger projects. Smart growth on the other hand as proposed by planners in the US is seen to be a better way to build and maintain towns and cities be it in urban, suburban and rural communities given the choices in housing and transportation.

The literature indicates that Smart Growth has led to more regulations, reduced affordability and found its principles largely unenforceable (Smith, 2015; Downs, 2005; Nelson & Wachter, 2003). The other approach called New Urbanism was expected to mitigate urban sprawl, seek sustainable growth and encourage infill development (Smith, 2015; New Urbanism.org, 2014; Garde, 2004). Some of its development principles include connectivity, mixed housing, quality architecture and urban design, sustainability and quality of life. Some criticisms to New Urbanism include its rigidity (Rowe, 1997), unaffordability and lack of economies of scale like Green Building. Local entities in the US and Canada have adopted LEED as well as universities and non-profit organizations in the belief for an alternative form of development. LEED could be a form of urban sustainable development for areas with smaller demographics, help reduce energy consumption, and reduce pollution among others.

Challenge of Transformative Learning

In the 21st century, there are complex problems facing societies that fundamentally require the need to reframe and relearn how humans relate to each other and with the environment (Konig, 2015). As such, society in general need to re-organize their relationships and interactions between society, the economy and the environment. With diverse knowledge from the academia, professionals and a broad base of practitioners, we are fraught with challenges that require education and capacity building in the sustainability front (Konig, 2015). This suggests putting sustainability at the heart of university education in science through learning, research and teaching. The lack of prescriptive knowledge to building sustainable urban projects (Pizarro, 2015, p. 48); need academic institutions to deliver the know-how and translate knowledge into reality through the production of urban design that promote sustainability.

Challenge of 'Urban Sustainability' Concept

Another concern is the analysis of the 'urban sustainability concept' in the context of developing countries (DCs) where there are questions in transforming urban reality. Of tremendous concern is the problem of an estimated 1 billion of poverty-stricken urban dwellers in slums that deserve serious attention (Bolay, 2012; 2005). Ninety-four per cent of slum dwellers live in the DCs with the highest urban growth rate and least access to resources. The idea of urban sustainable development demands a multidimensional approach to urbanization in the South as a complex phenomenon. According to Bolay (2015, p. 85), a new approach to urban development that must be put in place involves a) a multidimensional perspective on new urban forms; b) participation of all stakeholders in designing and implementing the city's transformations; c) multiplicity of scale ranging from neighbourhoods to the edge of the city, outwards to urban expansion to regional scales; and d) use of different instruments allowing for combined social and urban processes with architectonic or urbanistic objects. The point is that positive change is not solely dependent on architects or urbanists and other professionals in the field of urban development. Rather, what is required is a combination of disciplines and professions in planning for a built-up environment as a project for urban governance such as changes in business relationships among partners in local urban initiatives (Bolay, 2012; Jouve, 2008). In sum, cities deserve attention in any analysis for sustainable urbanism to find solutions as they deal with a multi-dimensional mix of environmental, financial, social, demographic and urban governance issues.

Challenge in the Delivery of Green Urbanism

There is growing knowledge on green urbanism produced in universities but the question becomes: What are green cities? Are they built with compactness, public mass transit, mixed land uses and pedestrian environments (Pizarro, 2015)? What we need is to apply the most advanced sustainability principles in developing sustainable urban projects in new urban spaces whether in energy generation, wastewater recycling organic waste reuse or enhancing urban biodiversity (Pizarro, 2015). What is the academic way of conceiving sustainable cities? Academics differ (antithetically) while the development firms think of land and housing development whose main concern is the proverbial bottom line. In the delivery of realistic sustainable urban projects, academic urban projects will face the economic challenge in urban design thinking and in meeting the demands of real estate development as one of sub-sectors that could potentially be affected in the planning process. Suffice it to say, that "with the many unknowns about how to build sustainable cities, and in particular, the lack of prescriptive knowledge to build sustainable urban projects, schools have a vital role in the delivery of know-how and in translating such knowledge into reality" (Pizarro, 2015, p. 48).

Challenge in Assessing the Sustainability of Major Cities

The literature indicates a mounting interest in measuring sustainable cities while recognizing that sustainable development (SD) springs at the local scale, i.e., at the level of municipalities, cities or metropolitan regions (Tanguay, Rajaonson, Lefevre & Lanoie, 2010; Fan & Qi, 2010). Studies of this kind that seek to assess the sustainability of cities are found in cities located in both the developed and developing countries. Some studies reviewed used sustainable development indicators and indices that examined three dimensions, namely environmental, social and institutional and economic. For example, Tanguay et al., (2010), reviewed 17 of 23 studies they compiled that applied SD indicators and noted the lack of consensus on the conceptual framework and selection of indicators. In their own study, Tanguay et al., proposed a selection strategy for SD indicators to adopt a parsimonious list on SD components with an optimal but minimal number of indicators. From the 188 indicators compiled by this team, they used 29 indicators for the 20 categories for environmental, social, and economic components in their study. In reflection, the selection of indicators could be an arbitrary decision as sustainability research consider the desire to mirror local concerns within the integrated components of sustainable development while investigating scientifically-based assessment methods.

Major cities in emerging countries like China are experiencing rapid urbanization over the last five decades with serious burdens on overall urban environmental quality in many ways, e.g., an uneven distribution of the environmental burden (Fan & Qi, 2008). With the wide range of environmental issues, sustainable urban development has emerged as one of the top priorities in the developing world. In constructing the urban sustainability index (USI), Fan and Qi (2008) combined normalized measures of economic development and social equity from which their index had three basic components namely: economic index, environmental index and equity index. Another approach to sustainability assessment focuses on the urban ecosystem as part of the decision-making and urban planning processes. One early work on ecological planning that is relevant to the discourse is Howard's Garden City theory which introduced an ecological approach to urban planning and asserted to bring nature back to the cities with greenbelts (Wong & Yuen, 2011). To Yigitcanlar and Dizdaroglu (2015), the purposes of an 'urban ecosystem sustainability assessment' are to: a) define sustainable development targets and assess progress in meeting targets; b) revise the effectiveness of current planning policies and assist in making needed corrections relative to changing realities; and c) compare over time and across space a performance evaluation and provide the basis for planning future actions. This assessment has been perceived as a powerful tool to connect past and present activities to future development as noted by Hardi, Barg, Hodge, and Pinter (1997) and Lamorgese and Geneletti (2013). Urban ecosystem sustainability assessment commonly uses sustainability indicators and composite indices for assessing sustainable land use and urban management (Yigitcanlar & Dizdaroglu, 2015; Yigitcanlar & Kamruzzaman, 2014).

Challenge of Urban Sustainability and Planning for Sustainable Cities

With sizeable impacts of rapid urbanization, an enormous challenge that cities and societies have been going through call for resilient planning and development perspectives (Yigitcanlar & Lee, 2014). In this context, 'sustainable urban development' as a contemporary paradigm is seen to address the impacts arising from the challenges of rapid urbanization. As such an opportunity for the search for new mechanisms to develop approaches for building an urban future is perceived. According to Yigitcanlar and Lee (2015), sustainable urban development of cities is aimed at improving the quality of life, including ecological, cultural, political, institutional, social and economic components to form a 'sustainable city'. In considering the important role of cities for wealth creation and greater life opportunities, Keivani (2010) has outlined the challenges that cities posed for sustainable development. On the social front is the presence of intra-urban social inequalities in both the North and the South as evidenced by relative income poverty and crime, and concerns over severe exclusion, among others. Economically, many cities in both the North and the South face the challenges for sustainable economic growth. Cities in the North struggle with economic restructuring in a globalizing era with loss of major industries and past economic roles (Keivani, 2010). Cities in the South suffer from institutional weaknesses and lack of material and financial resources coupled with the lack of strategic economic vision, compartmentalized sector-based policy making and need for coordination among various levels of government.

Urbanization in the developing world such as Bangladesh is a 'growing phenomenon' that raises serious concerns over urban sustainability due to lack of good governance (Rana, 2011). As a case in point, the situation in the country is considered to be more dangerous with the urban poor and the informal life in precarious environments to be among the issues toward sustainable urban development. Rana cites Dhaka city as a growing megacity (cities with population in excess of 10 million) currently faced with major challenges of rapid urbanization. In creating sustainable cities in Bangladesh, an important problem is the rapid urban growth that could pose challenges toward formulating strategies for urban sustainability. With its total urban population at 28.6 million and the annual exponential growth rate at 3.15% as of 2001, the country's urban figures has doubled every 12 years (Rana, 2011). Dhaka's population is 30% of total urban population, of which 37% are poor. Most notably, Rana raised the issue that population growth has outpaced service provisions like water, sanitation, waste disposal and housing. Rapid urbanization in the South is seen to be part of the dilemma of economic development and environmental suffering and that there are consequential challenges for urban sustainability as is the case of Dhaka city's water supply problems along with inadequate infrastructural services, natural and human-made hazards and poor urban governance.

Challenge of Alternative Models: The Unbalanced Model for Sustainable Urban Development

Are there alternative models to urban sustainability? One important challenge to Khakee (2014) concerns the issue of geographical scale in sustainable urban development because it has not received much attention in sustainability research. Environmental responsibility placed upon an individual, according to Khakee (2014), deflects attention away from broad economic and social factors that encourage lifestyles harmful to the environment. Further, he cited possible urban sustainability initiatives that could range from policy measures such as public transportation, increasing the density of urban development and new ecotowns or ecosuburbs. His work proposed a model of unsustainable urban development based on an old theory in development economics called unbalanced growth. The idea of spatial imbalance is argued to provide a feasible approach for cities to carry out city-wide sustainable development, noting the messy, everyday reality in urban areas. Here, the view is that sustainability in one part of the city could produce spin-off effects in the entire city. The unbalanced approach is seen to help break the inertia of attitudes and institutions; bring about necessary reactions to pursue sustainable changes in the entire urban society and break the current economic, social and political malaise in cities (Khakee, 2014).

FINAL REMARKS

Research in sustainable cities is an emerging and important substantive field of study in Sustainability Science that relates to planning, urban sustainability, urban design and assessment methodologies. The challenges reflect a shared interest in researching sustainable cities to address the prevailing issues affecting cities around the world. The scholarly works reviewed in the Chapter give a strong basis for further reflection on urban planning and design and most importantly, for stressing the need for robust research on the sustainability of urban areas. There are notable challenges advanced by current research in the review. *First*, the review noted a diversity of definitions and interpretations of sustainable cities in the same way that the terms ‘sustainability’ and sustainable development are debated in development discourses. *Second* is the persistent quest for urban design in efforts to find the solution to issues concerning sustainable planning. The pressing need is to find planning and design solutions to deal with urban sprawl, rapid urbanization, urban population pressure, degraded water quality, air pollution and soil erosion and so on. In seeking urban design solutions, the planning and research communities have stated the need to re-examine the demographic picture of city life to address the sheer volume of people in urban areas particularly in megacities around the world. *Third* is the need to continue with the analysis of the ‘urban sustainability concept’ not only in the context of developing countries (DCs) where there are questions that arise in transforming urban reality. About 94% of slum dwellers live in DCs and these are the people with the least access to resources. Research suggest that the idea of urban sustainable development should take a multidimensional approach to urbanization being a complex phenomenon in the South. Urban development should involve the participation of all stakeholders in designing and implementing the city’s transformations, engage a multiplicity of spatial scales from neighbourhoods to the edge of the city and outwards to urban expansion to regional scales; and use different instruments to allow for combined social and urban processes. It is argued that positive change may not solely come from architects or urbanists and other professionals in urban development but from a combination of disciplines and professions in planning for a built-up environment and urban governance. The sustainable urban development of cities could improve the quality of life, including ecological, cultural, political, institutional, social and economic components to form a ‘sustainable city’. *Fourth* is the question of how the academia is conceiving sustainable cities. There is no agreement as to how the term is framed by academics and the development firms where land and housing development are at the crux of their proverbial bottom line. In the delivery of realistic sustainable urban projects, academic urban projects face the economic challenge in urban design and the demands of real estate development as affected in the planning process. *Fifth* is the attempt to develop an assessment methodology to measure sustainable cities. There is a considerable interest in measuring sustainable cities while recognizing that sustainable development (SD) springs at the local scale, i.e., at the level of municipalities, cities or metropolitan regions. Finally, as environmental concerns become part of development discourses, there is optimism in the refinement of the process to create 'sustainable cities' in the near future.

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Chapter 10
Integrating Inner and External Dimensions for Holistic Sustainability

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ABSTRACT

Over the past century, sustainability scholars and scientists have largely focused on the complex relationships between society, economy, and environment. The authors refer to this approach as external sustainability research, which positions the built and natural environment as key to a sustainable future. Yet, our external environment is a manifestation of deeply held beliefs, values, attitudes, and perceptions of the world—the inner dimensions of sustainability. Within sustainability science, a deeper understanding of the inner dimensions could promote lasting external sustainability measures, strategies, and interventions. This chapter envisions sustainability as a holistic collection of internal and external guiding principles that can be enhanced through practice. First, the authors draw on perspectives from "Western sustainability" and Indigenous philosophies. Next, case studies integrating holistic

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sustainability approaches are shared. They conclude by integrating the primary literature with the case studies and call on sustainability science to more deeply consider the inner dimensions.

NTRODUCTION

Sustainability is often cited as a relatively new concept born from the 1987 Brundtland Report (Brundtland et al., 1987). Yet, the origins of sustainability science go as far back as the 17th century, if not further, when Western imperial European governments mobilized to prevent deforestation. At the time, the rapid consumption of woodland (Europeans removed about 25 million hectares of woodland between 1700 and 1850 – equivalent to the surface of the State of Michigan or a little over the surface of the United Kingdom; Williams, 2003) coupled with a disregard for nature, and an increase in population growth and civil unrest, worried European empires, propelling them to exert resource conservation measures. The term sustainability was officially coined in the early 18th century by Hans Carl von Carlowitz, founder of the Sustainable Yield Forestry principle. He is credited with sketching out the structure of modern sustainability discourse after analyzing connections among forest shrinkage and advances in technology, the propagation of diseases, social unrest, and conservation measures (Caradonna, 2014).

Since then, sustainability has been developing by co-evolving through economic, political and social revolutions that have taken place in Europe and North America; namely the industrial revolution, the social contract, the green revolution, the civil rights movements, and population booms, among others. This trajectory led to its official academic conceptualization in the Brundtland Report and the multiple redefinitions concerned with human progress and development as safeguards to current and future natural resources, social systems, and economies (WCED, 1987; Jones et al., 2011). In parallel over the last two decades, sustainability research has grown with a focus on indicator and criteria development to shape sustainability science. Recent efforts focus on the design of "solutions" in response to a comprehensive list of local and global sustainability challenges (Hartmuth, Huber, & Rink, 2008; Ingold & Balsiger, 2013) (e.g., links between food systems and local economies, connections between over-consumption of natural resources and poverty). Inherently, a trend has continued from the early days of von Carlowitz's attempts to address deforestation. This is what we refer to as external sustainability in this chapter.

We also observe this trend outside academia, where sustainability science has been presented to the general public as strategic solutions to mobilize pro-ecological movements including recycling, community gardens, and organic foods, or strategies such as shifting to low energy light bulbs or turning to solar panels (Noppers et al., 2014; Grometa, Kunreuthera, & Larric, 2013). But a solutions-based mindset may have offset the potential to achieve meaningful and lasting results. While solutions involve important processes and actions to support the move toward a sustainable future, a limited perspective, drawing only on external fixes, can be systematically detrimental to global sustainability goals. In other words, many modern sustainability solutions may see only the symptoms of a problem, while ignoring the root cause originating from individual and collective values, beliefs, and attitudes. Sustainability science is beginning to integrate these aspects under inner sustainability — a realm that considers the root causes of sustainability challenges.

Horlings (2015) describes inner sustainability as an individual process of change from the inside out, based on a person's values, beliefs, and attitudes — also referred to as inner reality in this chapter. Yet, inner sustainability is more than that — it involves self-reflection and acknowledgment of actions led by experienced feelings, emotions, and needs. Acknowledgment can be guided by self-reflection of one's internal values and principles — the result is an exercise to promote inner development, which inherently affects our perspective of external states. Modern society largely fails to acknowledge inner sustainability as a legitimate component of sustainability science research and practice. In fact, before the concept of sustainability was created by northeastern European empires, indigenous societies around the world, out of necessity, operated via holistic sustainability philosophies that not only focused on external realities, but also on the inner dimensions. The development and evolution of sustainability as a concept has been a major influence in separating its holistic components, giving priority to external sustainability.

The present chapter proposes to re-integrate the inner and external dimensions of sustainability as a holistic lens for sustainability research and practice while also empowering individuals in every group of society. With that in mind, the chapter objectives:

- Highlight the relationship between inner and external sustainability.
- Speak to the importance of inner values and beliefs for holistic sustainability.
- Present an overview of the separation between inner and external sustainability by highlighting the evolution of "sustainability" as a concept in the Western world.
- Highlight indigenous living philosophies as models integrating inner and external dimensions of sustainability.
- Present integrative case studies as examples of holistic sustainability research and practice.
- Instigate a desire to understand and cultivate inner sustainability.

BETWEEN TWO WORLDS

Although the concept of sustainability can be traced back to European governmental measures, sustainable practices have long been an integral part of multiple cultures around the world. Holistic approaches to sustainability do not separate humans from “Nature,” promoting a conscious relationship between humanity and the spectrum of ecological diversity. In fact, without a sense of superiority or dominance, many populations have been able to cultivate collective and individual external and internal balance without the urgency to exploit or problem-solve their surroundings. Such philosophies include the Quechua/Kichwa Sumak Kawsay, the Diné Hózhó wellness, the Maya Cosmos, and the Hawaiian Aloha ‘aina, all of which promote the connection to land and values of reciprocity, community, empathy, and love.

Indigenous philosophies can enhance current sustainability teachings to achieve a holistic sustainability state given their capability to integrate behaviors and actions to patterns of Nature. Being an integral part of nature meant the community would observe ecological patterns, learning when and how to act and to gather resources mindfully. The “rational” thought of taking advantage of nature was unconceived, as it would harm the individual and the community. Thus, indigenous groups from the past, and to a certain extent in the present, integrated a sophisticated understanding of natural patterns that served them to lead internally and externally balanced lives (Ulluwishewa et al., 2008).

Modern society is “learning that we are a planet of many societies, each harboring different visions, and perspectives that are, in fact, alternative realities. Acknowledging the equality of these different realities is a matter of human justice” (Freidel et al., 1993, p. 36). We build on this perspective by claiming individuals have the opportunity to learn from multiple sustainability perspectives by embracing the wisdom from each. The following section presents several cases of indigenous living philosophies and ways we can integrate such examples into sustainability research and practice.

The Amawtay Wasi Cross-Cultural University (Garcia et al., 2004)

The university, located in Ecuador, was founded in 1998 — following work by the Indigenous Nations of Ecuador dating back to 1987 — as a project to bring multicultural understanding and ancient indigenous knowledge to its curriculum. The Cross-Cultural university aims to provide education to all as a constitutional and international human right. The school is founded on four living indigenous principles, including:

1. The Principle of Relationism: All beings are connected and depend on each other. Under this principle, there is no supremacy to build relationships of mutual respect. Knowledge derives from practicing community learning and by being in communion with Mother Earth (Pachamama).
2. The Principle of Complementary Duality (karywarmikay): Indigenous philosophy views opposites as required for the existence of the other, which makes opposites complementary to each other. An example of duality is rational knowledge and myth. The former exists because of the existence of myth. Myth is a different way of accessing knowledge: it requires intuition and exploration of the inner reality of individuals.
3. The Principle of Living Symbol: The symbols, rituals, myths, body language, ritual festivities, and other events related to daily life hold a sacred place in the community. These components affirm cultural identity.
4. The Principle of Reciprocity (ayni): One must give first in order to receive. This philosophy goes beyond material goods - knowledge, stories, and wisdom are part of the daily exchange in the community. The cyclical process of sharing knowledge and receiving is what allows the community to grow and continue.

Diné (Navajo) Hózhó Wellness Philosophy (Khan-Jhon and Koithan, 2015)

The wellness philosophy of Diné people integrates harmony, respect, and spirituality embodied as six living principles for a happy life:

1. Human beings are whole systems, inseparable from their environments. We are connected not only within ourselves but also to other people and to the environment that surrounds us. Being connected and having the support of our communities helps us maintain healthy physical, mental, emotional, spiritual, and existential levels.
2. Human beings have the innate capacity for health and wellbeing. This philosophy looks at the mind, body, and spirit as a sacred connection. A person can maintain health, balance, and happiness by following six living principles of Hózhó. When one has irresponsible thoughts and actions, unbalance and unhappiness fall upon the life of the individual. Healing ceremonies are performed to heal the person to return to a state of balance.
3. Nature has healing and restorative properties that contribute to health and wellbeing. Diné people see nature and all its elements as sacred components that must be respected. These elements provide humans with food, shelter, spiritual healing, and guidance.

4. Integrative nursing is person-centered and relationship-based. One must have an understanding of oneself and a connection with the body-mind-spirit. Embracing the sacredness of this three-dimensional self allows the individual to be a grounded person and to have an authentic relationship with others and with nature. A special connection and sacredness with the home one inhabits must also be present. It is important to understand that everything in nature surrounding the individual is sacred, and for this, one needs to maintain relationships by means of practicing generosity and reciprocity.
5. Integrative nursing is informed by evidence. Hózhó wellness philosophy embraces all healing methods that lead to wellbeing (this includes physical, mental, emotional, spiritual, social, and environmental wellbeing) no matter the origin of the practice. This philosophy considers well-being from a holistic lens and does not discriminate against any type of holistic medicine (e.g., Western medicine, spiritual healing ceremony). This approach allows for inclusion and understanding of different cultures.
6. Integrative nursing focuses on the health and wellbeing of caregivers as well as that of those they serve. One needs to show respect to the healer or caregiver by presenting a gift or token to this person. This is a way to reciprocate the care that the healer or caregiver gave to the person in need.

Maya Cosmos (Freidel et al., 1993)

Ancient Mayans performed intricate rituals to connect with the Otherworld, placing the world as the center of the universe. They spoke to spirits from the Otherworld and brought them to village life, politics, trade, and intercommunity warfare. This allowed interaction between the spiritual and physical worlds to be fluid. Mayans also believed in daily renewal of the earth, meaning that nothing is permanent, and everything is continuously evolving. Community life was essential for a healthy culture and mind. This continual interconnectedness was one of the key aspects of the sustainability of the culture. Some of their living philosophies include (Reina, 1984):

1. Communion with the sacred: Spaces where rituals are performed are the home of the creator spirit. One must behave with respect toward the spirit and nature. Shamans — individuals trained to communicate with the Otherworld — are the intermediaries between these interactions.
2. Connectedness with nature: Nature lives within humans and humans live within nature. Mayans used their senses to be attuned to the voices of nature.
3. Self-reliance and self-sufficiency: Humans grow by learning to rely on their senses and their skills. Humans have the capacity to meet their needs and solve

their problems. Over-reliance on external resources leads to less self-reliance and self-sufficiency, and loss of magic.

4. Connection to place: The land is more than a physical place to live. It is home to the ancestors where culture had developed throughout time. Mayans have a deep sense of attachment to the place from which they came.

Native Hawaiian Principles (Chun, 2011)

Traditional Hawaiian beliefs encompass a sense of connection between the self, family, and community. Two important concepts are *Pono,* the right way, and *Aloha*, the action and expression of love. In traditional Hawaiian culture, a sense of hospitality is critical because of the importance of building community. Traditional principles include complex cultural and spiritual norms which inform right action and belonging in many facets of life. Guiding principles include the following:

1. *Welina:* Treat all people with hospitality, bring a welcoming spirit to the community.
2. *A'o:* Education emerges as a bond in the community. Experience and learning are shared and communicated within the group to build a sense of belonging and individuality within the community.
3. *Ho-omana:* Prayer is integrated into culture and involves asking for divine help with specific actions. Traditional Hawaiian religion is polytheistic and animistic. While today there are no formal temples or dogma, Hawaiians refer to prayer and spirituality as *ho'omana*.
4. *Aloha 'aina:* Paramount in traditional Hawaiian beliefs is a sense of loving connection to the land — called *aloha 'aina*. Love of land, links Hawaiians to nature, defining a spiritual and temporal relationship with the land that informs resource use and society.

As illustrated by our reviews of indigenous living philosophies, holistic inner and external dimensions are considered important parts of a sustainable future. The principles and guidelines all contain socio-ecological wisdom accumulated from generations of culture. Yet, the vast world of wisdom and values within indigenous cultures is oftentimes disregarded within sustainability education and science. The mystic knowledge, spiritual rituals, and the notion of interconnectedness between humans and natural elements that different indigenous societies practiced have been regarded as primitive (Freidel et al., 1993). Via an ingrained "superiority mindset" of knowledge, morality, and technology, European colonizers globally exported values that diminished or eliminated indigenous learning. Consequently, the theory of a rational mind has been, by many, considered superior to the world of imagination and magic (Anzaldúa, 2009) and, as it is detached from inner sustainability, has led to unbalanced societies and losing of culture with resource over-consumption, rapid environmental degradation, and psychological problems. This is not to say that indigenous societies were ideal conservationists (Raymond, 2007) or non-violent and non-competitive. Rather, both inner and external realities were acknowledged as equally important for individual and community growth. The result may have been a more balanced lifestyle than what is predominant in modern societies. In the section that follows, we provide some brief case studies striving for balance, or the integration of inner and external sustainability research and practice.

CONNECTING THE TWO WORLDS: CASE STUDIES

The following case studies document both in-progress and completed research that integrates inner and external dimensions of sustainability. By highlighting these cases, we hope to demonstrate sustainability as both inner and external realities: both complement each other as a holistic sustainability research and practice approach.

Showing Up: Coming Together for a Just and Sustainable Future

The external changes needed to realize "sustainability" in Western culture require a significant inner shift. Globalism and the growth mentality continue to feed the expanding need for resources by exploiting indigenous communities and devastating the environment (Whyte, 2013 & 2017; Reo & Parker, 2013; Maldonado et al., 2013), while loneliness has become an epidemic in modern society. Without a rich, grounded social network, an awareness of history and ties to the land, the modern person lives in a sheltered-nuclear household, stuck in a loop of fleeting gratification (Putnam, 2000; Haidt, 2006; Slater, 1990). Those who cannot afford the consumerist lifestyle are increasingly pressed, while the affluent may not see the effects of their actions on others. To make matters worse, the design of American homes, businesses, and public structures and the lack of common spaces in our communities reinforce separation (Alexander, Ishikawa, & Silverstein, 1977).

The fields of development, planning, and community psychology have shown that we cannot realize possibilities beyond what we already know until we come together to acknowledge injustice, allow all voices to be heard, and work toward equity (Fussell, 1996; Perkins, 1995; Pigg, 2002, Gone, Hartman, & Sprague, 2017; Dufrene & Coleman, 1994; Wallerstein & Duran, 2006; Yellow Horse Brave Heart & DeBruyn, 1998). With trust, we can begin to envision a decolonized, sustainable, and inspired future -- *and this work is not as slow as it sounds*. I arrive in the field of sustainability science as an artist who creates sculptural spaces for respectful, safe dialogue. I have observed groups of former strangers become ready to creatively address the challenges and opportunities in their neighborhoods after only a couple of hours together. I am striving to replicate this process.

At this time, I am committing myself in service to the Skid Row community in downtown Los Angeles, California. Nearly 50,000 people are in need of housing in Los Angeles today, and downtown's Skid Row has become a public health catastrophe (LAHSA, 2017). What was once a central core of a few city blocks has spread across the city as an alternate reality of tents, addiction, mental illness, and other signs of a broken system. The mayor and members of the City Council are committed to helping alleviate the issue, yet, it is a very complex situation (Garcetti, 2015; Narayan, 2018).

I am forming a Skid Row artmaking collective that will envision and co-create an urban ecovillage as a remedy for chronic homelessness and unsafe conditions. Our efforts are focused on creatively moving toward sustainable inner and external sustainability. We will use a collaborative sculptural technique to objectify difficult emotions that come up in dialogue and physically manipulate them until the form represents a shared ideal. The group will be introduced to sustainable building practices from around the world and throughout history, in order to expand our collective imaginations of what is possible. As we challenge and question existing codes and social norms in the world around us, we will investigate resources and relationships that will help us take steps toward a more sustainable and equitable reality. Should the community decide to re-imagine neglected urban sites as villages of small adobe homes and gardens, I will introduce experts in those areas who will work with us collectively.

I will be measuring and validating the work via academic methods and standards. Since I believe that the essential motivation of all human behavior is to feel appreciated and connected (Cacioppo & Patrick, 2008; Baumeister & Leary, 1995; Richerson & Boyd, 1998), I use qualitative methods to gauge individual and collective wellbeing over time. Axial analysis (Glaser & Strauss, 1967; Glaser, 1978; Strauss & Corbin, 1998; Charmaz, 2014) of ethnographic observations, interviews, and surveys, with literature in the fields of loneliness, connection, and design, will attempt to paint the picture of what happens for people in these collaborative processes. I will also document workshops, artwork, and discussions with photography and video, and share the story through popular publication. The real proof of efficacy through collective processes in Skid Row might range from subtle but triumphant expressions of deepened trust to grand gestures of radically different building styles and organizations of space. However, my only intention is to commit my energy as a member of the community and bring my experience, education, access to resources, and creative inspiration to the table. Sustainability calls for people of all socioeconomic backgrounds to reach out beyond consumerist isolation and connect with one another internally and externally: myself included.

Living in a Wounded World: Sustainability and Psychological Trauma

Study of psychological disorders can benefit the field of sustainability by exposing the ways that an individual's internal psychological or emotional environment can mediate their relationship with external social and ecological environments. While the significance of inner sustainability might seem abstract to some conditioned to an external perspective, it can also be very concrete. Sustainability scholarship has begun to pay attention to the importance of individuals' psychological health and cognitive processes. For instance, Clayton (2007) looks at the psychological cost of climate-related disasters and Goldstein, Martin, and Cialdini (2007) consider the power of social proofing in decisions related to consumption and waste. However, these insights seem to represent exceptions to the rule, as the field continues to rely heavily on outdated rational actor hypotheses. In reality, "the experimental facts indicate the need to develop more realistic models of human behavior under uncertainty, acknowledging the complexity of real-world decisions and our species' limited information processing capabilities" (Costanza et al., 2017). More holistic incorporation of psychological insights into sustainability research and scholarship, and closer collaboration between experts in both fields could lead to improved outcomes and valuable new understanding.

My research, focused on military veterans impacted by psychological trauma, reveals a dire sustainability problem that has not yet been recognized, and which carries implications for solution formulation and dissemination. First, I apply diagnostic criteria for what constitutes a sustainability problem from Wiek's Transformational Problem-Solving Framework (2016) to qualify veteran trauma as an "internal" sustainability challenge with "external" sustainability consequences. Second, I suggest that symptoms of some psychological conditions undermine sustainability initiatives across all sectors.

The Transformational Problem-Solving Framework posits that sustainability problems exhibit all of the following criteria to a varying degree: They are urgent and constitute significant harm over the long-term. Their effects are dispersed – both spatially and temporally, and they are exceedingly complex. Finally, they are often the center of intense disagreement (Wiek, 2016). Combat-related trauma, as experienced by US military veterans in the forms of Post-Traumatic Stress Disorder (PTSD) and Moral Injury (APA, 2013; Litz et al., 2009), fulfill all of these criteria.

The urgency lies in the rising prevalence of trauma and the high risk of suicide it brings. The rate of PTSD in veterans increased thirteen-fold between 2003 and 2012, and 20 veterans commit suicide per day (NAS, 2014; VA, 2016). Trauma is harmful in that it prevents individuals from fully participating in social settings, including workplaces, where avoidance, emotional numbing, and hyperarousal symptoms make interpersonal interactions difficult (NAS, 2014; Van der Kolk, 2014). Spouses and children are at heightened risk of secondary traumatization as a consequence of the first individual's symptoms, and children of traumatized veterans are more likely to develop physical and mental health issues if exposed to inter-relational violence (Elbogen et al., 2012; Nash, 2013; PTSD, 2015; Hom et al., 2017). Finally, acknowledgment of trauma has been closely bound to political debate (Herman, 2015) and a negative cultural stigma which sees trauma or any other mental illness as a defect or sign of weakness discourages those who need treatment from seeking it (Wachen et al., 2016).

It is important to realize that veterans are not the only members of the population that are vulnerable. Many professions are more likely to be exposed to traumatic events, like first responders, as are some unfortunate population subgroups, such as kidnapping victims. Study of Moral Injury, in particular, exposes the fact that even people that never directly experience traumatic events are vulnerable. Furthermore, symptoms of veteran-typical trauma are antithetical to values and principles associated with sustainability and the actions required by sustainability initiatives. Trauma symptoms lead to social withdrawal, lack of focus, nihilism, suicidal thoughts, and many other burdensome states (APA, 2013). These characteristics are perfectly at odds with the kind of collaborative, optimistic, far-sighted, and empowered action that the most important sustainability issues require. Therefore, it would be wise for sustainability advocates to plan for the possibility of trauma symptoms inhibiting meaningful adoption and adherence to sustainable behaviors and values.

One way this could take shape is by partnering with psychologists and using local historical analysis and sociodemographic information about a region targeted for a sustainability intervention to produce a probabilistic psychological risk profile, then customizing certain aspects of the solution to ensure maximum uptake. For instance, the case-study I looked at – agricultural therapy as a treatment enhancement for traumatized veterans – as well as my own fieldwork, revealed that participants respond most strongly to those aspects of recovery initiatives that foster teamwork, a sense of purpose, hard work toward a worthwhile goal, and contributing to their community (Brown, 2016; Besterman-Dahan, 2018). A sustainability team, attempting to increase community buy-in for, say, a low-income community with a recent history of police brutality or gun violence, could promote their initiative in a way that would emphasize those same aspects in the context of their solution.

Trauma is nothing new. Nor is depression, anxiety, or most psychological disorders. What is new to modernity, however, is the erosion of the means we have evolved to cope with – community connectedness, a strong and integrated identity, and interaction with nature (Schumaker, 2001; Twenge, 2017; Roszak et al., 1995). In this climate of political discord and corruption against the backdrop of multiple converging environmental crises and existential threats, the loss of those coping strategies is keenly felt. If more and more people continue to succumb to trauma and other disorders that hinder sustainability, the future will not be a sustainable one, regardless of innovations in engineering, technology, or institutions.

The Colonizer Mentality

Addressing climate change has been the motivating factor behind much of my research. During my undergraduate studies, I focused on the external dimensions of physical science research as I thought solutions lied within. Climate change is caused by excessive greenhouse gases — if we could simply find a way to reduce or capture greenhouse gases we could stop climate change, I thought. As I am educated within Western society, I originally thought that addressing only the physical side would work. My undergraduate education contributed to this view as much of what I learned emphasized the importance of technology and external scientific solutions. In fact, in 2009, researchers discovered potential to become 100% renewable by 2030 with the technology we have today — all that was missing, the author stated, was the "political and social will" (Jacobson & Delucchi, 2009).

Western society tends to address symptoms rather than root causes. If one has high cholesterol, for instance, a Western doctor might prescribe pharmaceuticals; on the other hand, Naturopathic or Eastern medicine might address diet and lifestyle changes as root causes. Such an approach integrates inner and external dimensions of sustainable health. Much like conventional Western medicine, however, treating climate change with technology and science alone will not address the root causes. In fact, relying on technology and science alone might actually create more problems as the system is complex (van der Leeuw, 2012). For instance, renewable energy (which might address climate change symptoms and even root causes) relies on precious metals extracted by means that promote environmental degradation (Brand, 2012). Currently, nearly half of solar panels produced in the world come from China (Mulvaney, 2014). The country is known for its unethical labor practices with limited environmental regulations and solar panel production processes that create 30% more pollution than when produced in Europe (Yue et al., 2014). The competitive nature of the market system can even cause the USA to compete with unethical practices, leading individuals to resort to using prison labor to produce solar panels (Groom, 2015). Even if renewable energy is developed without precious metals, and fair wages are paid, we are only treating symptoms. The challenge doesn't lie in a lack of external resources to transition to a renewable economy; rather, we lack the necessary inner values and beliefs expressed as political and social will to support such a transition.

As I became aware of the prevalence of solutions to symptoms, rather than processes to identify and work on root causes, I changed fields and approaches. I went from researching carbon dioxide to conducting research on how to communicate climate change in conservative communities. I conducted field experiments and community based participatory research projects to understand how conservatives might accept climate change science. What I found through my own research and others (Poortinga, 2011; Stoll-Kleemann et al., 2001) is that many conservatives don't want to be affected by the changes needed to address climate change. Climate change denialists believe acting on climate change goes against their values because climate change is a collective action problem and Western culture is an individualistic society (Waugh, 2011). From here I begin to wonder, what are Western values? Where do Western values come from? How are they perpetuated and why do they persist? My research will begin to answer these questions and make the case that the root cause of climate change stems from societal and cultural values.

My hypothesis is that tenants of Western culture including individualism, egoism, control, and competition come from colonialism. The result is a "colonial psyche" that makes us act as short-term thinking and self-centered beings with a focus on growth and immediate gain. Ultimately, the psyche affects our ability to care for those more vulnerable than us — including minorities and the planet. I suggest that, as climate change is a collective action problem and Western culture is usually individualistic, we must address the inner dimensions listed as colonial attributes above. Otherwise, we will be unable to address climate change in a manner that takes into account the needs of future generations and all people on the planet. This hypothesis is based on my lived experiences and research as a climate activist, scientist, and policymaker for the last several years. I suggest climate change research should integrate the inner dimensions of sustainability to bring lasting change. Addressing the inner dimensions of sustainability can be done by means of increasing social cohesion, building community, protecting cultural diversity, creating new values for modern society, and creating healing spaces in colonized communities and nations. To many in Western society, this may seem impossible, but arguably it is what needs to be done for our collective survival and ultimately, thriving.

Regenerative Development: Integrating Inner and External Sustainability to Co-Evolve Thriving Living Systems

Regenerative development is a design and development methodology that grows capacities in living systems to manifest increasingly higher levels of complexity, well-being, and vitality (Benne & Mang, 2015; Mang & Reed, 2012). Regenerative development intentionally integrates the inner and exterior realms of existence, and inner and external dimensions of sustainability to develop a regenerative culture in which humans and nature co-evolve and thrive (duPlessis & Brandon, 2015; Hes & duPlessis, 2015; Mang & Reed, 2012; Wahl, 2016). Regenerative development is based on an ecological worldview that incorporates knowledge from ecology, quantum physics, systems science, spirituality, and indigenous cultures. It understands that all life is connected through dynamic material and non-material flows and relationships across scales of space and time. This interbeing entails ethics of respect, care, and responsibility for all life (duPlessis & Brandon, 2015).

Regenerative development was recently used as a guiding framework for an award-winning design in the Ala Wai ahupa'a (watershed) in Honolulu, Hawai'i (USA), co-created through collaboration between Arizona State University graduate students and faculty, Hawai'i Green Growth, and Hawai'i inhabitants in 2017. We conducted an integral assessment, gathering information to understand the interactions, development, and emergence as a whole of the geophysical, ecological, and human components of the system through time and space. We began at the archipelago (island chain) scale, then moved to the island of O'ahu, then to the Ala Wai ahupa'a. The process relies on always considering one scale up (e.g., the role of the island in the archipelago) to understand the context and meaning of patterns in a place and one scale down to understand creative forces giving rise to meaningful characteristics of a system that emerge from processes and relationships. We also conducted deep listening sessions with stakeholders and inhabitants in order to understand and embody their knowledge, experience, and vision of their place. In short, a deep listening session involves practitioners receiving information given in a spirit of humble curiosity with clarifying questions and no judgment. We were seeking to uncover the defining essence and purpose of the Ala Wai ahupa'a so that we could co-create designs and developmental change processes that would allow its life-giving patterns, processes, and relationships to manifest in perpetuity.

We came to understand water as a powerful organizing, life-giving force here. Indigenous Hawaiians were able to prosper by co-evolving, with nature, a culture based on ahupa'as. Their spiritual beliefs of belonging to a larger, interconnected community of life, with each part playing a value-adding role to the well-being of the larger whole, led to values of reciprocity of and responsibility for intentions and actions and their effects on all life throughout the ahupa'a and beyond. These values, in turn, led to vitality and prosperity for all life in ahupa'a systems and throughout the archipelago that lasted for 1500 years before colonization, fragmentation, and industrialization in the 1900s turned an inherently regenerative system into a degenerative one. We based our design on this understanding, integrating culture and nature into an ecocultural approach for a contemporary ahupa'a.

We knew that a whole watershed developmental approach working across scales was needed to regenerate the system. We made integrated design suggestions at the watershed, community, and site scales that would enhance life while nurturing the indigenous knowledge and culture (i.e., ecological worldview) necessary for the perpetuation of well-being and prosperity (mauō) throughout the ahupa'a. We proposed physical and social organizational structures and processes similar to those that existed in indigenous ahupa'as. Smaller communities would follow a regenerative development process and make decisions about how best to increase prosperity within their community and contribute to the well-being of the larger communities of which they are a part. At larger scales, municipal officials or other governing bodies would provide support and guidance to ensure that sufficient actions for system-wide regeneration and prosperity were being taken and to follow a similar process at the island and archipelago level.

Site-level design proposals included three large-scale infrastructures that would contribute to larger ahupa'a regeneration. These infrastructures included affordable housing, community space, wetlands, bioswales, boardwalks, and flood-activated walls. Together, they would regenerate the original function of the ecosystems in this particular location, including flood control, water purification, habitat and biodiversity creation, and facilitation of flows of materials, nutrients, energy, and information. They would also provide cultural heritage opportunities, tourist opportunities, and generate funds to pay for Waterhood development. They would thus add economic value while adding social, cultural, and ecological value. They would also nurture deep care for place and an ecological worldview as well as create educational, economic, and social relationships for mauō throughout the system. By integrating inner and external dimensions of individual and community life, the project aimed at providing lasting change that empowered community members and reconnected the social sphere with the ecological environment.

Food Is Culture

In recent decades, as external sustainability became predominant in research and practice, the world shifted towards an industrial commodity-based food system which has had significant cultural implications worldwide. The idea that food nourishes the body and the soul as part of culture was gradually abandoned in many Western communities. Food has become a commodity, giving a few top global companies significant control over food. The result is that bottom-level consumers are conditioned to think that "their food comes from multinational companies rather than from farmers and the earth" (O'Kane, 2016, p. 219). Cultures lose autonomy and identity when they are drowned out by the one-sided decisions that our food system can make for us.

We have always needed to expend energy in order to obtain enough food to survive. From these norms, vibrant food cultures began to take shape. Cultures were identified by the food humans chose, the regions they cultivated, cooking methods, and the social norms of eating. Now, we find cultural identity in the food choices we make including whom we purchase our products from, how we prepare our food, who we chose to eat with, and how much time we dedicate to food preparation and to eating. The disconnect between our inner world and external reality have led us to disregard where our food comes from, leading to homogenization of food cultures. If we all eat the same way, we lose our cultural identity, worsening the resilience of humans as a whole.

These ideas sparked my interest and got me thinking about the possibility of local food as a driver and strengthener of collective cultural wellbeing. In the summer of 2017, I participated in Sustainable Food Systems, Community Development, and Happiness in Denmark study abroad program. This study abroad program took me to community gardens, food halls, and diverse neighborhoods in Århus, Denmark where I was able to draw connections between inner and outer sustainability as it relates to food. The program was flexible and allowed me to create my own research topic on connections between local food and cultural wellness in the town of Århus, Denmark. In order to assess the effects of a localized food system on cultural wellbeing, I visited food spaces such as farmer's markets, community gardens, street food vendors, and local restaurants in and around the city. I set up multiple interviews with farm-to-table chefs, farmers' market vendors, managers, and consumers. Back in Phoenix, Arizona, I conducted a similar qualitative research for a comparative analysis of Århus and Phoenix. There were around six interviews in each city that I used to formulate my results. Most interviewees held the belief that food can be a powerful tool for human connection, cultural prosperity, and inner balance when used correctly.

The study shows that although it is different for every person, cultural wellbeing can be defined as balance between utmost cultural expression and cultural ignorance. Cultural expression is revealed through a feeling of place in one's culture and the making of culturally relevant choices. Cultural ignorance is being unaware of how actions influence one's own culture, or by disregarding the importance of culture altogether. The balance between the two stems from experiencing cultural diversity, being cognizant of how daily choices affect culture, sharing cultural practices with others, and taking part in cultural activities. A resilient food culture system is one that empowers consumers to connect with nature and choose healthy food options. Being reintroduced to the idea of food as a miracle of nature rather than a vacuum-packed commodity could spark a resurgence of balanced food cultures and integration between inner sustainability and external behavior. I believe that there is enormous potential in where the food culture of our society is headed, and with some mindfulness and intention, we can direct our path toward one of cultural celebration that integrates the inner and external components of sustainability.

SOLUTIONS AND RECOMMENDATIONS

Holistic sustainability research requires an understanding of complex situations while at the same time seeing the big picture. Interconnectedness of life is one of the principles that sustainability scholars should be actively mindful of when engaging in research and practice. And since sustainability issues can be quite complex, urgent, unique, irreversible, and have an undefined solution (Remington-Doucette, 2017), it is important to have an open mind when engaging in research and practice as well as to collaborate with community members. Holistic sustainability is about looking at how the inner world of individuals — values, beliefs, and attitudes — influence our actions in the world, and understanding that external sustainability issues are the result of the inner components of the individual. The recommendations of this chapter are to reconnect with the inner dimensions of one's sustainability to be able to understand the important role that inner and external dimensions play in holistic sustainability approach. The other recommendation is to embrace all types of knowledge and learning — scientific and non-scientific, Western and indigenous — in holistic sustainability research and practice. An open mind will allow sustainability researchers, scholars, practitioners, students, and community members to work with a mindful heart allowing lasting change to emerge.

FUTURE RESEARCH DIRECTIONS

The present chapter was a collaborative process among individuals who are looking at holistic sustainability as an ethical way to engage in research and practice. Each one of us has a different future research direction, but what we all have in common is the commitment to engage in inner sustainability research to understand the roots of problems. In the larger field of sustainability, research incorporating the inner and external dimensions is necessary to address evermore pressing global sustainability issues. There is no "best" area of research to engage in holistic sustainability. Every research direction that looks at the system from a holistic lens will be meaningful to its own field and will be more likely to bring lasting change for the common good.

CONCLUSION

Sustainability started as a field to address problems in the natural environment, which later gave birth to sustainability science. The expansion of Western societies into "new" territory, and the globalization that resulted from that allowed nations to transform the natural world to meet human demands for consumption and expansion. Gradually, the holistic lens of sustainability was cast out to only leave the external component of this science. External sustainability seeks to apply solutions to problems experienced in the environment of the individual and the community. Often, these decisions are developed by individuals outside the community in positions of power and privilege (Ledwith, 2011). Such a dynamic can promote or preserve values and beliefs that may have caused challenges in the first place (e.g., overconsumption or competitiveness), as the affected individuals are not given the chance to collectively reflect and envision their own future.

The inner components of sustainability — values, beliefs, and attitudes as well as the spiritual realm — was usually disregarded in Western societies. However, holistic sustainability was and is still practiced to a certain extent in indigenous cultures because their life philosophies organically integrate the inner and external dimensions. Indigenous philosophies tend to place a higher value on the interconnectedness of life, which can be experienced through inner sustainability. Many indigenous societies see inner life as an important component of living. The external world provides resources to satisfy the needs of human societies; yet, the inner world must not be forgotten. A balance between both worlds brings stability to life, and this balance leads to holistic sustainability.

The Chapter proposes that inner dimension efforts to promote mindfulness and collaboration are more likely to inspire lasting change than working exclusively on external solutions. Sustainability scholars and scientists who work directly with community members as collaborators can help facilitate fruitful endeavors by building trust and reciprocity, developing personal relationships, and promoting community: all involved are more likely to understand and respect each other's values, beliefs, and perspectives. This sort of understanding and mindfulness between individuals can be the foundation for inspired co-creation and the shift toward a sustainable future. We suggest that developing principles like humility, gratitude, generosity, reciprocity, stewardship, accountability, and compassion could translate into inner sustainability and, as a result, more sustainable individual and collective actions. Agreeing to share values and beliefs is a powerful way to create collaborative and innovative environments necessary to achieve large-scale sustainability (Sai Manohar & Pandit, 2014).

The scientific research and case studies demonstrate that sustainability science can be more powerful and comprehensive when it is inclusive of the inner and external realities of individuals as well as of cultures and traditions in the larger built environment. Inclusion of and respect toward individuals different than us is essential to creating spaces of trust, compassion, and emergence of holistic sustainability ideas where everybody benefits. Especially, inclusion of groups historically targeted as inferior by Western society (e.g., minorities, indigenous groups) can teach us about different cultural and indigenous philosophies that have a holistic view on life: humans, animals, and the natural environment are interconnected and belong to the same ecosystem. Going from efforts to address homelessness in Skid Row, CA, to understanding PTSD and moral injury in US military veterans, to addressing the root of climate change by understanding colonization, to working on regenerative development projects, to reconnecting with food, these projects look at the bigger picture while addressing small-scale initiatives. Holistic sustainability looks at the implications of all variables and highlights that external sustainability issues are only the symptoms, while the root of the problem can be found by looking at the inner dimensions of sustainability. Integrating inner and external sustainability research and practice is a pathway to create meaningful shifts toward lasting sustainability at the individual, local, regional, and global levels.

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KEY TERMS AND DEFINITIONS

Collective Action: Working together with different groups in a mindful way to include everyone in the conversation and to empower every individual involved.

External Sustainability: Science that positions the built and natural environment as key to a sustainable future.

Holistic Sustainability: Science that integrates dimensions of inner and external sustainability for a lasting sustainable future.

Indigenous Philosophy: Understanding of the world that past and current indigenous societies around the globe have of what constitutes good living. In general, indigenous philosophies viewed the world from a holistic lens.

Inner Sustainability: Values, beliefs, and attitudes that serve as the inner foundation of individuals.

Inner World: Values, beliefs, and spirituality that compose the intangible self of individuals.

Interconnectedness: Understanding that everything in life is connected: from humans to the natural environment, to the inner world and external reality, to inner sustainability and global sustainability challenges.

Western Society: Groups of individuals who come from a Eurocentric background and who have adopted the individualistic culture from it. In the chapter, we are referring specifically to mainstream American culture.

Chapter 11
Place-Making and Sustainable Community Development

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ABSTRACT

This review chapter explores place-making in terms of how it is linked with sustainable community development (SCD). Place-making as it relates to sustainable community development has not been understood in the practice of sustainability, urban planning, and community development. Here, place-making is a process of planning, designing, managing, and programming spaces to create patterns and activities in cultural, social, economic, and ecological terms to achieve a better quality of life, a prosperous economy, and healthy environment. As informed by research, it can be an approach to sustainability thinking as a strategy for transforming cities and public spaces to promote well-being and prosperity in a local place, urban area, or neighborhood. In the long-term, the theory and practice of sustainable community development relative to place-making will evolve and eventually produce well-grounded meanings and conceptualizations as we engage in more research on sustainability and sustainable development.

INTRODUCTION

The concepts of place-making and sustainability have been contested within research and practice in community sustainability. One of the most important things about sustainability as a development concept is the claim that the economy and the environment are inextricably linked (Hopkins, 2013; Lempert & Nguyen, 2008; Martin & Mayer, 2008; Mayer, 2008). To have economic growth and sustainability

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is to say that we understand the need to find the balance between sustainability and economic development. Sustainability remains at the center of discursive terrain in research and policy debates in the global environment and development arena. Invariably, sustainability is characterized by three pillars (social, economic and environmental) (Hempel 1999; Goodland 1995). If expressed differently, the idea of 'sustainability' is well-positioned in terms of the 'triple bottom line' comprising the economy, the environment and society in discursive narratives about place-making in urban areas, towns and places. Although there is a critical need to examine place-making and community sustainability, we have yet to understand how they are linked together in shaping the planet's future. By examining how place-making is defined, it informs environmental thinkers, researchers, policy makers and leaders in the industry and sustainability science of its relationship with community sustainability. Despite burgeoning literature, the relationship between 'place-making' and sustainable community development is unclear in conceptual sense whether they overlap, diverge or exhibit a shared interest within the science of sustainability. As such, this is the lacuna that the current interest on community sustainability study seeks to fill.

While there is dynamism in sustainability as an expanding field, the spatial dimension for policy decisions and actions in place-making has been neglected in sustainability thinking. The question is this: How does place-making create or influence sustainability? Towns, cities and municipalities are pivotal to development as they contribute 85% of gross national product in high-income countries (Friedman, 2010; Keivani, 2010). In the South, concerns on urban problems such as rising population, environmental degradation and resource scarcity have been identified (Keivani, 2010; Drakakis-Smith, 1995). In the North, cities continue to build massive infrastructure and initiate projects that reflect a complex picture of contradiction and fragmentation rather than a promise of sustainability (Williams, 2009). Since cities are places of cultural and social interaction as well as centers of political and economic power, it is important to consider their myriad challenges to sustainability (Keivani, 2010). With parallel issues on environmental degradation and world poverty, the poor in the developing countries are primarily concerned with earning a living than caring for the environment (Keivani, 2010; Drakakis-Smith, 1995). On the environmental front, cities are the largest contributor to greenhouse gas emissions affecting the world climate (Keivani, 2010). In economic terms, cities and towns in Canada and elsewhere have placed emphasis on municipal investments, growth of local economies and community development alternatives in pushing for economic prosperity and sustainability (Turvey, 2015). Although it is essential to deal with questions of 'what' or 'who' is to be sustained, the question of 'where' and/or 'which place' is becoming sustainable (or unsustainable) is equally relevant to sustainability studies. This geographic dimension has not been a key research issue in the field's literature as current academic and policy interests are limited in dealing with the question of 'what places and surfaces on Earth can become sustainable?'

As Seamon and Sowers (2008, p. 43) put it, "History has time, Geography has place." A place can include the natural world, the built-environment or Earth environment in the context of human-nature relations. A place can be found in nature and nature can be regarded as a place, a physical world or a natural world to interact, as described in the dictionary. Place can be any undisturbed landscape to be used and explored by humans or something to be overcome or nurtured, if not conquered (Entrikin, 1991; Hartshorne, 1979). Places, urban areas- large or small are faced with a diversity of environmental issues from climate change to resource depletion, biodiversity loss and other global problems. To sustain life, we have to strive for Earth's sustainability by addressing the ecological concerns for the planet to survive indefinitely. The concept of *place* as context with an active role and presence in our local worlds, whether to initiate, act and transform the organization of, and interactions in space is vital to sustainable development, economic prosperity and societal well-being. The word 'place' in sustainability defines '*where', 'how'* and '*why'* sustainable development as a process occurs, since sustainability does not occur in a vacuum. Apart from its spatial character, a place has specific temporal, social and human dimensions that contribute to shaping places and particular human experience of them. Scholarly attention to the geography of sustainability is important to the study of place and place-making. What place is confronting sustainability issues? The spatial dimension has been left out in conceptual analysis when looking at sustainability as a goal and process for place-making. One may ask: Is this assertion a conceptual or practical necessity? This aspect of sustainability has been taken for granted in mainstream studies despite efforts to create places into sustainable communities over the past three decades, hence the focus of place-making and sustainable community development in this Chapter.

BACKGROUND

Broadly, place-making is defined in several ways (Arefi, 2014; Friedmann, 2010; Sorensen & Funck, 2007). In this inquiry, place-making is a process of planning, designing, managing and programming spaces to create patterns of activities in cultural, social, economic and ecological terms to achieve better quality of life, a prosperous economy and a healthy environment. It can be an approach to environmental thinking in sustainability terms as a strategy for transforming cities and public spaces based on the community's assets, development goals and potentials, to promote well-being, happiness and overall health in a local place, urban area or neighborhood. Place-making can be a collective undertaking by individuals and communities through the synergies of local inputs and bottom-up participation where people play an active role in environmental improvement and management processes (Sorensen & Funck, 2007). It is about creating livable neighborhoods with government getting local initiatives underway and encouraging neighborhood institutions and associations where making places is everyone's job (Friedmann, 2010).

There is a substantial body of literature on 'place' in everyday use but the same may not be said about place-making in environmental context. Place-making is everyone's concern- whether you are a local resident, a politician, professional planner, architect, conservationist, environmentalist, sociologist, technologist, and so on. Current literature on place-making is embedded in a range of disciplines that conceptually engaged the topic not only from planning and design but also from geographical and building perspectives. Some academics and practitioners involved in a sustained inquiry argue that "it is about the critical capacity of the place-making process itself to confirm and interrogate the place-becoming" (Schneekloth & Shibley, 1995, p. xiii). Though it is a way all of us change or transform a place into places in which we live, work and visit, there are relatively few treatments written by sustainability scientists and environmental scholars that link place-making with sustainability. Contemporary place-making theory is different from place-making in the 1970s, 1980s and even the 1990s. Current place-making puts greater emphasis on positive and prescriptive rather than normative and proscriptive studies (Arefi, 2014, p. 97). While theorists in the 2000s generated theirs from a review of best practices and use of case studies, today's studies on place-making are based on context-specific research in place-making. In critical theory, place-making is an intrinsic part of the social practice of place where both people and place play a simultaneously dependent role (Seamon, 2012; Abdelwahab, 2006). In fact, there is the matter of 'attachment' to place which can be subjective but constitutive of a place (Friedmann, 2010). As Seamon (2013) puts it, "Phenomenologically, a place can be defined as *any environmental locus in and through which individual or group actions, experiences, intentions and meanings are drawn together spatially*" (Casey, 2009; Relph, 1976).

Like place-making, place attachment is rarely static and Seamon's (2013) idea is to bring attention to the *generative aspects of place*. With six place processes, Seamon (2013) identified two groupings for *place interaction*, *place identity*, *place release*, *place realization*, *place creation* and *place intensification*. On the one hand, *place interaction, place identity, place release and place realization* are those that "describe what places are and how they work". On the other hand, *place creation* and *place intensification* could indicate "how positive human effort and well-crafted making can improve place, or through an inappropriate understanding and constructions, can activate place decline (Seamon, 2013). As explained, *place creation* is about improving places and human beings are active in relation to place and as such, people have a responsibility to, and draws on their commitment and empathetic knowledge of a place to make creative shifts in policy planning and design. However, it can also be a process that undermines when it comes to thinking and making those results in misunderstanding or ignoring the real needs of place. When it comes to *place intensification*, Seamon (2013) argues that the 'independent power of well-crafted policy, design and fabrication could review and strengthen a place.' Place-making can be associated with 'place creation', and even 'place intensification' where positive human efforts and well-crafted making can improve places where human beings are active in relation to place (Seamon, 2013). These ideas articulate the consistency of, and support to the idea of improving places and making places stronger, more adaptive to change, whatever the physical challenges are, toward a 'robust environment synergy'. Another view of place-making concerns "daily acts of renovating, maintaining and representing the places that sustain us, and of special, celebratory one-time events such as designing a new church building or moving into a new facility" (Schneekloth & Shibley, 1995, p. 1).

The conceptualization of place-making and sustainability indicate that: a) most definitions provide a variety of meanings with shared understanding of our planet Earth in confronting a range of developmental and environmental problems to find sustainable solutions; b) there are scholarly conceptualizations that mirror the response of the global research/policy community to the challenges of sustainability concept, and c) there is no universal definition of urban sustainability perhaps due to varied contexts and perspectives. The concept of sustainability is a process of 'creation, maintenance and renewal that persists in balance with the process of decline' (Hempel, 1992). Others have stressed how it could be applied for decision-making and management, advocacy, consensus building and analysis from a favorable, more acceptable view of the usefulness of the term (Parris & Kates, 2003). To Rogerson, Sadler, Green & Wong (2011, p.1) sustainability is likened to an established brand, not only that (it) expresses an "…aspiration to manage resources more effectively, but also one that imbues policy making and thinking with sensitivity towards rebalancing environmental, social and economic dimensions." Cultural-specific definitions are not covered here but it should be stressed they are equally important in understanding the connection between place-making and sustainability. Each culture may have a different interpretation of what is sustainable development and sustainability, depending upon their value systems, overall outlooks on matters pertaining to the environment and so on. The next section discusses sustainable community development (SCD) and provides definitions of sustainable communities.

UNDERSTANDING 'SCD' AND SUSTAINABLE COMMUNITIES

Broadly, there is a surging interest in the discussion of a 'sustainable society', sustainable world' and 'sustainable community.' If the scenario is set into the people's everyday life in local spaces, a potential exists for the so-called sustainability condition to have concrete evidence or proof in daily life (Bridger & Lulof, 2001, p. 380). Where do we find these successes? The world just needs to look at the North American and UK/European examples of efforts toward creating sustainable communities featured in textbooks (Roseland, 2012; 2009; 2000; Hempel, 1999). Somewhere and elsewhere are local economic and environmental initiatives and people mobilized through bottom-up interventions to address the issues on the economy and the environment. Yanarella and Levine (1992, p. 769) has observed that "…sustainable community development (SCD) may ultimately be the most effective means of demonstrating that sustainability can be achieved on a broader scale, precisely because it places the concept of sustainability in a context within which it may be validated as a process." What is being embraced by scholars and practitioners is the view of sustainable communities promoting interdisciplinary and cross-cutting approaches to problem framing and policy response.

But first, what is a community? A community could spatially mean local places. In regard to place, belonging to or existing in or peculiar to a place (local history), a community means one's own neighborhood affecting a part and the whole (Entrikin, 1991, p. 26). Another way to define it is based on Shaffer (1989, p. 3) as "a group of people in a physical setting with geographic, political, and social boundaries and with discernible linkages." There are four ways to describe it- *first* as belonging to a geographical location, *second* as defining a particular local social system, *third* as a sense or feeling of togetherness, and *fourth* as an ideology with power relations that underlie communities (Richards & Hall, 2000). From a spatial context, how is 'community' defined? Politically and geographically, it is 'a place where space is defined by political boundaries of a municipality' (Shaffer, Deller & Marcouiller, 2006, p. 59). According to Mason (2000, p. 21), the ordinary concept of 'community is "constituted by a group of people who have a range of values, a way of life, identify with a group and its practices and recognize each other as members of that group". To others, a 'community' means a valued achievement and a moralized concept because it is based on shared interests, solidarity, equality, and other forms of association not strictly tied to particular places (Williamson, Imbroscio, & Alperovitz, 2002; Mason, 2000). Increasingly, the concept of community stresses the role of active local agencies, the nurturing of civil society and mutual recognition within a community's economic life.

Some critics who thought sustainable development as oxymoronic were pleased to replace the word 'development' in sustainable development with '*community*' (Hempel, 1999). Although the dynamic field of sustainable development has broadened the research agenda, far less thought has been paid to how communities could become 'sustainable communities' in the long-term. Although there is a wide variety of ways to explain what a 'community' is, Henrickson et al., 2011 defined it as 'geographic communities of place represented by municipal, local or Aboriginal jurisdictions (p. 59). From a global perspective, Williamson et al., (2002, p.1) defined communities by shared interests, organizational membership, race and ethnicity or other forms of association not strictly tied to particular places. In the context of community development, there are fundamental links for community building which includes economic growth, prosperity and security, community sustainability, and building cohesion with actors/stakeholders. Bridger and Lulof's (1999) arguments are rooted in place-based communities. With the heterogeneity of local places, a one-size fits all is not possible. Why? Local communities differ in the nature of environmental problems, natural resources, economic and social situations, physical and climatic conditions (Bridger & Lulof, 2001, p. 381). A community-level approach is more appropriate in the design and practice to match potential opportunities and constraints in particular places seeking community sustainability. While sustainability is about the protection and conservation of living and non-living resources, the community needs to constantly respond and adjust their strategies and other assumptions to make development work and make the community sustainable. Next is to address the following question: Why does it make sense to focus on the local and community level to operationalize sustainable development and the idea of sustainability?

Focus on Sustainable Community Development (SCD)

Rapid progress and developments in sustainability science and the global research community have stressed the need to integrate an approach reflecting solutions that are interdisciplinary, transdisciplinary in our outreach to society (Turvey, 2015; Leemans and Solecki, 2013). Terms like place and 'community' in sustainability are key organizing and planning concepts to interpret the site, setting and function as well as relations, connections and interactions between and among places in sustainable community development (SCD). Community sustainability is used interchangeably to mean SCD defined with interests on local quality of life, population pressures and inter-temporal equity. There is support for considering sustainability in three pillars-namely social, economic and environmental dimensions. Sustainable community development defines the relationships between the local quality of life and local/regional levels of population, consumption of resources, political participation and commitment and inter-temporal equity (Hempel, 1999). Conceptually, SCD is a place-making process of planning, design, transformation and capital mobilization, e.g., the use of human capital in development activities (Turvey, 2015). SCD is an interdependent planning and implementation framework on strategic directions, strategies, actors and instruments for municipal place-making; examines how the economy influences the unsustainable development of local jurisdictions and how a coherent typology of strategies, actors and policy levers can move communities toward complementary environmental, social and economic outcomes for developing the built environment (Henrickson et al., 2011).

What Are 'Sustainable Communities'?

'Sustainable communities' as a concept remains to be a contested concept and lacking a widely- accepted definition (Rogerson et al., 2011, p. 9). If one is to examine the ideas of relevance, coupling rather than decoupling of the economy, the environment and society are fundamental elements for building a sustainable community. For instance, Hempel (1999) examined the implications of sustainability concepts and their applications in real-world communities. Sustainable communities are sometimes referred to as green cities, eco-cities, sustainable cities, eco-communities and livable cities; they can be any type of neighbourhood, town, city or region. Based on the work of Mazmanian and Kraft (1999), the idea of sustainable communities is not really new; historical perspectives includes the garden city movement (Howard, 1898), bio-regional planning and design (Geddes, 1915), spaceship Earth idea (Fuller, 1969) resilient ecological communities and architectural visions of neoliberal towns and healthy cities (Van der Ryn & Cathorpe, 1993). Roseland (2005) stressed the potential and economic dimensions of community sustainability relative to growth management, urban ecology and environmental planning. In this context, a sustainable community "resembles a living system in which human, natural and economic elements are interdependent and drawing from each other" (CSCD, 2016). An important point made here is that lasting gains in the quality of life cannot be achieved without effective integration of environmental, social and economic goals at the community and regional level.

The concept of 'sustainable communities' was used in Agenda 21 following the sustainable development model in the UK and elsewhere (UN (a), 1996; UN (b),1998; ODPM, 2003). The ICLEI's (2002) planning guide suggested a collective vision for creating and transforming communities into a 'sustainable community' committed to the three E's of sustainable development, namely environment, economy and equity (UN, 1998). There is a tendency to move from a narrow focus in the 1960s on environmental sustainability towards a more holistic view, which emphasizes the role for communities but includes environmental, social and economic principles of sustainability (Marsden & Hines, 2008; Agyeman 2005). Hempel (1998, p. 48) defined a sustainable community as a 'community with economic vitality, ecological integrity, civic democracy and social well-being to foster a high quality of life'. The term 'sustainable communities' lacks a universal definition and characterized by its hybridity (Rogerson et al., 2011; Marsden, 2008). While many definitions exist, it remains unclear beyond how a sustainable community might evolve on the ground. Although there is no widely accepted definition of 'sustainable communities' (Rogerson et al., 2011), current literature is not short of meanings and interpretations. While it is essential for a place to define the term from a local perspective, a dilemma is created by the growing diversity of contexts and perspectives. Conceptually, since it is drawn from the discourses of sustainable development, debates on governance reform can be characterized with hybridity and varied meanings but the primary focus remains on local interest. In the 1990s, an international social movement on community sustainability has emerged (Mayer, 2008; Innes & Booher, 2000). Initially it was used in the Agenda 21 Planning Guide from the sustainable development model in the UK and elsewhere (OPDM, 2003; UN, 1998). The notion of creating sustainable communities is at the heart of SD policy in the UK, Canada and others (Environment Canada, 2010; DCLG, 2007). The term is often associated with conservation and consensual stability; others link it with the notion of 'self-sufficiency' (Thomas & Littlewood, 2010). First, it draws on the discourses of sustainable development based on the three pillars of social, economic and environmental sustainability. Secondly, 'sustainable communities' draws on discourses based on the relationship between the local government, the communities, the private sector and stakeholders to delineate the responsibilities of communities and change the cultures of planning regimes (Rogerson, et al., 2011; Roseland, 2009; 2012; Marsden, 2008). While it is essential for a community to define it from a local perspective, the conceptual gap is not the lack of a well-recognized definition of sustainable community because the meanings vary by context, perspective or purpose. Further, 'sustainable communities' tend to move away from its narrow focus of environmental sustainability in the 1960s towards a more holistic recognition of the environmental, social and economic principles of sustainability and the roles communities play (Marsden & Hines 2008; Agyeman, 2005).

In contrast with the positive view of a sustainable community, a community could become unsustainable if and when they assume abundant and cheap energy and poorly managed; rising urban sprawl, high carbon dioxide production per capita, faced with high ecological footprint and issue of carrying capacity given a more populous urban environment. Overall, the path forward in conceptualizing sustainable communities is about transforming communities, tackling deprivation, creating a new planning system and integrating the public and private voluntary sectors, among others. Such communities are often engaged in promoting and meeting their needs, in the present and the future through planning and implementing environmental management strategies. Sustainable communities can be grouped into different types, including communities defined from the perspective of policy and planning, resource management, quality of life, integration of social, economic and environmental dimensions and local governance. Thus, the goal towards better quality of life, nature's ability to function overtime and revitalized natural resources dominate recent state of knowledge (Bridger & Luloff 2001; Hempel, 1999; UN, 1998; SEDEPTF, 1995;). As an integration concept, the notion of 'sustainable communities' offers a set of mutually enhancing goals, including ecological integrity, economic security, high levels of quality of life and citizen empowerment, for purposes of planning and policy (Kline, 1995).

Specifically, SC thinking is the involvement of dominant players and contributors with important, distinct roles such as:

- **Environmentalists:** Think of social and economic needs
- **Developers:** Understand ecosystem management
- **Civic Leaders:** Recognized interdependence of communities in economic and ecological terms
- **Ordinary Citizens:** Connect civic engagement and quality of lif*e*
- **Economic Developers:** Engage in economic planning, management, attraction and creation of jobs and investment

As cited earlier, Bridger (1997) enumerated these five dimensions of a typical sustainable community:

1. Emphasis on increasing local economic diversity
2. Promoting self-reliance with development of local markets, local production, processing of previously imported goods
3. Reduction in the use of energy coupled with the careful management and recycling of waste products
4. Protection and enhancement of biological diversity and careful stewardship of natural resources
5. Commitment to social justice

Several definitions of sustainable communities exist in the current literature and compiled here based on their links and similarities. Sustainable communities are described by what community means by its local structure and the goal for achieving quality of life. The Research Center for Sustainable Communities at Lakehead University define it as: communities that are environmentally sustainable, economically vibrant and socially just in terms of their goals, processes and practice of meeting the present and future needs of the generation with respect to the use of resources and management of the economy and the environment (RCSC, 2014). Another definition that puts emphasis on high quality of life is that of Hempel (1999) where a sustainable community has "economic vitality, ecological integrity, civic democracy and social well-being linked in contemporary fashion, thereby fostering a high quality of life and a strong sense of reciprocal obligation among its members" (p. 14). The United Nations publication of Agenda 21 in 1996 also supports the need to engage stakeholders in decision-making, address geographical inequalities in the local quality of life and employment; adopt a bottom-up rather than top-down approaches and relate to the concept of Agenda 21 and its Actions toward sustainable development. Similarly, Kline (1995) referred to sustainable communities as those that represent the successful integration of four key objectives: ecological integrity, economic security, high levels of quality of life and citizen empowerment with added responsibility. Others viewed sustainable communities by the community's local structure. Bridger and Lulof (2001) described sustainable communities as communities that do not just describe one type of neighborhood, town, city or region as they differ from community to community with regard to their activities that the environment can sustain, what citizens want and can afford. They argue that it is not a fixed one, but a community that is continually adjusting to meet its needs while preserving the environment's ability to support it. While there is no universal definition that exists, sustainable communities as seen from a local perspective presents the gains and pains of adjustment that should be shared by community members within the process of democratic mobilization as may be necessary, given that there could be a dilemma of how to encourage participatory local processes (Roseland, 2009). Further, sustainable communities are associated with its emphasis on the three pillars of sustainability where its meaning implies a more holistic, integrative and dynamic view of communities that support the principles and processes of environmental sustainability, economic prosperity, social justice and community well-being (Turvey, 2015). In pursuit of a sustainable development model, sustainable communities are viewed to develop economically, socially and environmentally and must respect the needs of future generations now. This is the key to lasting rather than temporary solutions (OPDM, 2003, p. 5). In addition for such communities, the political factors and cultural development trends in a community are deemed invaluable for developing places into sustainable communities. Increasingly, some definitions of sustainable communities have given a close link between the community and its resource management. In Minnesota, USA, sustainable communities are seen as communities that use resources to meet their current needs while ensuring that adequate resources are available for future generations. As they set a goal for high quality of life for all its residents, their objective is to maintain nature's ability to function over time by minimizing waste, preventing pollution, promoting efficiency and developing local resources to revitalize the local economy. The community is deemed to resemble a living system in which human, natural and economic elements are interdependent and draw strength from one another (Minnesota SEDEPTF, 1995). Moreover, sustainable communities are defined as “healthy communities where natural and historic resources are preserved, jobs are available, sprawl is contained, neighborhoods are secure, education is life long, transportation and health care are accessible, and all citizens have opportunities to improve the quality of their lives” (President’s Council on Sustainable Development, 1996, p. 12).

From the nineteenth century to the present, progress in creating ‘sustainable communities’ has been deemed difficult and patchy, even with the best intentions to transform a community into a place desirable to its residents for a better quality of life. ‘Sustainable communities’ can be grouped into different types, including communities defined from the perspective of policy and planning, resource management, quality of life, integration of social, economic and environmental dimensions and local governance. Alternatively, a sustainable community could refer to communities that continually adjust to meet the social and economic needs of its residents while preserving the local environment (Bridger & Luloff, 2001). Thus, the goal towards better quality of life, nature’s ability to function overtime and revitalized natural resources dominate our recent state of knowledge (Bridger & Luloff, 2001; UN, 1998; Hempel, 1998; SEDEPTF, 1995; Nozick, 1992). As an integration concept, the notion of ‘sustainable communities’ offers a set of mutually enhancing goals, including ecological integrity, economic security, high levels of quality of life and citizen empowerment, for purposes of planning and policy (Kline, 1995).

Roseland (2005) stressed the potential and economic dimensions of community sustainability relative to growth management, urban ecology and environmental planning. Mazmanian and Kraft (1999) included within their sustainability community criteria four clusters of capital: natural capital (capital theory with nature as capital); urban design (land use, planning versus markets and design with nature); ecosystem management (systems thinking/ecology) and metropolitan governance (regionalism and intergovernmental cooperation). These ideas are useful contributions for understanding what a sustainable community is. A sustainable community can be planned, built and modified to achieve sustainable living. Increasingly, Canadian cities and small urban municipalities put the green focus as part of their local development initiatives and in response to municipal legislative frameworks in place such as the ‘Integrated Community Sustainability Plan’ in Ontario. They recognize that a ‘healthy economy’ needs a ‘healthy environment.’ In the US, the green paradigm is widely promoted in local economic development initiatives to innovate, prosper and at the same time care about the planet (Rangwala, 2008, p. 27).

FINAL WORDS

This review explored the meanings of place, community and sustainable communities before a discussion of the linkages between place-making and sustainable community development. Since Lester Brown pioneered the concept of sustainable development in the 1970s, concepts such as sustainability and community sustainability (or SCD) have emerged in research and policy development in sustainability science, natural resource management and environmental studies (WCED, 1987). In theory, temporal and spatial characteristics shape individuals' and groups' experience in terms of the conceptual analysis of place-making and community sustainability. In hindsight, the conceptualization of community sustainability is evolving with a diversity of definitions with no universal definition. Based on a discursive review of community sustainability and place-making, both concepts share the same objectives. There are no overlaps but certainly have similar interests in terms of what is to be sustained or how life is maintained on this planet. Are there misconceptions and conceptual flaws? In the more recent past, their meaning was unambiguous if not misused and abused but currently the synonym for sustainability is 'good' for everything that is positive (Karoly, 2011, p. 1). There is strong evidence that both concepts show interrelated interest to create a normative framework for shaping a sustainable world. Broadly, sustainability does not simply exist in quotation marks as some argue where the power of the concept lies in the discourses surrounding it (Redclift, 2005).

While place-making can be a positive and dynamic function in planning, design and management terms, community sustainability as a goal means the state of maintaining and sustaining the life-support systems, maintaining natural capital, improving the quality of life and so on as we reach for an indefinite life on Earth. Place-making and sustainability are complementary but not mutually exclusive, parallel yet distinctive. *First,* place-making assumes the functions of constructing, maintaining and fixing whatever is essential to keep a place in acceptable, running condition to serve the purpose for which it is designed, built and managed for human use. *Second,* SCD is not in conflict with place-making because the former focuses on managing natural resources, ensuring ecological services are sustained, and promoting intergenerational and intra-generational equity. In lived spaces, inhabited places of human beings, they do not exist only for a moment of time. Places are making history as they have a past and a future (Friedman, 2010; Lefevre, 1996).

In the 21st century, everyone contributes to the discourse of sustainability as an integral aspect of the three-pillar view of (economic, social and environmental) sustainability. Inputs to SCD can be by a group or group of stakeholders, by profession or by corporate responses— through which collective, mainstream and everyday efforts generate meaningful contributions toward shaping a sustainable world. There is no reason to create confusion about community sustainability as it differs or relates to distributive justice, environmental security and social equity. The links between place-making and SCD could be sharper in discourses concerning their functional relationships and meanings. Academics, practitioners and policy makers will continue to build, rebuild, transform, and shape the character of places to create a legacy to the future. The question is to find out ways to construct places for building a sustainable city or town, hence this focus on place-making within the framework of 'community sustainability'. We can continue to carry out research and find solutions to transform towns, cities and municipalities into sustainable communities. They can be transformed through a process of place-making with development and environmental strategies in place to achieve community sustainability.

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* * *

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