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Sustainability Thinking in Agriculture: Review of the Last Four Decades

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ABSTRACT For a long time, human beings did not worry about the consequences of their actions on the environment. However, post the Industrial Revolution, rampant rise in production and consumerism have stressed the earth's natural resources to such an extent that humans are now making a conscious effort to "go green". Sustainability has become the new buzzword among academicians, practitioners, scientists, industrialists and students. This paper traces the evolution of the concept in the last forty years in the field of agriculture, following its emergence as a concept, its operationalization, its drivers and barriers and the frameworks that were developed to monitor and measure it. It attempts to provide a comprehensive definition of sustainable agriculture and identify points of divergence and commonalities in the measurement and monitoring frameworks. It highlights the interdisciplinary approach of the concept and the need for convergence of ideas for universal acceptance.

INTRODUCTION

Man has come a long way since the early days of agriculture where the reliance was on primitive tools, family/community labour, monsoons and conditions such as natural soil fertility and availability of water. Initially, gradual advances were made in production and storage techniques for centuries leading to small improvements which ultimately resulted in large scale commercial agriculture. The Industrial Revolution and developments in production techniques thereafter heralded an era of increased economic activity and consumerism. While it led to further production increases, the next big advance was the manipulation of genetics to create high yielding and pest resistant varieties of crops.

These advances eventually translated into development of industrial agriculture and intensive farming techniques characterised by monoculture, use of large sized farms, genetic manipulation of seeds and livestock, reliance on chemical fertilisers and pesticides and breaking away from natural cycles and ecological interdependencies. As the emphasis moved towards "better, cheaper and faster" production techniques, traditional processes and practices were side-lined. With the passage of time however, observed adverse effects on soil, water, organic content, genetic diversity losses and related factors have compelled some farmers and scientists to question the long-term viability of such practices leading to focus on the concept of Sustainable Agriculture.

Objectives

Briefly, the objectives of this paper are to:

- Provide a historical review and timeline of developments in the field of sustainable agriculture in the last four decades.
- Develop a comprehensive definition of sustainable agriculture.
- Identify points of divergence and convergence between different frameworks used in the measurement and monitoring of sustainable agriculture available in literature.

METHODOLOGY

The research design of this paper is exploratory in nature and relies on literature available in the field of sustainable agriculture. Academic

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journals, books and other documentary sources have been analysed to understand the depth of research that has taken place in the field. The research has been restricted to studies in the last four decades as this was the period when the concept has attracted maximum academic interest. The research questions concentrated on were:

1) How is sustainable agriculture understood?
2) How divergent is the understanding of the concept?
3) What are the drivers of sustainable agriculture?
4) What is the basis of assigning a factor as a driver?
5) How is sustainable agriculture measured and monitored?
6) What are the commonalities among the different measurement frameworks?

The Significance of Sustainability

By the 1980s, there was growing concern about the impact of human economic and commercial activity on the environment and natural resources leading to the United Nations setting up the World Commission on Environment and Development to identify possible ways to address the same. This resulted in the release of the Brundtland Report titled "Our Common Future" which contains the most popular definition of sustainable development which broadly implies development that meets the needs of the current generation without undermining the ability of future generations to meet their own needs (Brundtland Commission 2018). Essentially, the report suggested that all the nations of the world, irrespective of their economic orientation or their status as developing or developed, recognise the right of humans to their share of the Earth's resources and use them judiciously and fairly such that posterity does not feel the lack. This report was a landmark in the history of environmental protection and has triggered research and debates the world over in the areas of sustainable development and sustainability.

With different approaches and contexts, it is hard to find one universally accepted definition of the term sustainability. One study stated that sustainability is the capacity of a system to maintain output at a level approximately equal to or greater than its historical average (Lynam and Herdt 1989). In concurrence, the dictionary definition states that sustainability is the ability to be maintained or perpetuated at a certain rate or level (Oxford Dictionaries 2018). While this is a broad definition that can be applied to several contexts, it raises the question of how long this ability needs to be maintained to be "sustainable" indicating that time is an important factor. In his work on sustainability, population growth and the environment, Bartlett (2006) suggests that "sustainable has to mean for an unspecified long period of time." The time factor is vague and leads to assumptions in the operationalising of sustainability variables.

With respect to sustainability, the Brundtland definition relied on two aspects - development and the environment. The World Summit on Sustainable Development in 2002, widened the definition to three pillars - social, economic and environmental (Kates et al. 2005). In the social context, sustainability has been defined as a quality of societies which signifies nature-society relationships, mediated by work, as well as relationships within society. Social sustainability is given if work within a society and the related institutional arrangements (1) satisfy an extended set of human needs and (2) are shaped in a way that nature and its reproductive capabilities are preserved over a long period of time and the normative claims of social justice, human dignity and participation are fulfilled (Griessler and Littig 2005). In an economic framework, sustainability is defined by dynamic efficiency and intergenerational equity (Stavins et al. 2002). The maintenance of natural capital, in particular, the two fundamental environmental services - the source and sink functions, characterises environmental sustainability (Goodland 1995; Spash and Clayton1997).

The three aspects of social, economic and environmental sustainability were variously depicted as pillars, concentric circles and as overlapping circles. The International Union for Conservation of Nature adopted the interlocking circles model highlighting the interconnectedness and overlap between the three aspects and therefore a need for an interdisciplinary approach to sustainability (Adams 2006).

Sustainable Agriculture

Given the adverse impacts of industrial agriculture and intensive farming techniques such as pesticide toxicity, depletion of soil fertility, increased vulnerability to soil erosion, loss of biodiversity, pollution of water and other natural resources, falling of water table levels and negative impact on health of farm workers, there is a growing tendency among farmers and researchers to find alternative farming techniques that will ensure the sustained production of crops and profits. The focus is now on capitalising on synergies in nature, optimising the use and reuse of natural resources and minimising external inputs. When analysed not just as a process in nature, but also as an economic activity that provides employment and leads to social transformations, the need for an integrated approach becomes apparent. This integrated approach leads to the acceptance and adoption of practices that fall under the umbrella of sustainable agriculture.

Different stakeholders have attempted to define sustainable agriculture in their own contexts leading to a plethora of definitions that sometimes deal only with one or a few associated aspects. It has been described as a philosophy (MacRae et al. 1989), an approach that integrates land stewardship with agriculture (Neher 1992), a management strategy (Francis et al. 1987) and a range of strategies that will help cope with several agriculturally related problems (Lockeretz 1988; Rockström et al. 2017). Agriculture is defined as being sustainable when it is ecologically sound, economically viable, socially just, culturally appropriate and based on a holistic, scientific approach (Madden and Chaplowe 1997). Sustainable agriculture inherently has a long term focus, is place specific, holistic and understands that natural resources are finite (Horrigan et al. 2002). With changing external social, economic and environmental conditions, sustainable practices also need to be responsive and therefore are dynamic.

Drivers of Sustainable Agriculture

Despite increased awareness of sustainability in agriculture, modern unsustainable agricultural practices not only persist but are pervasive. Several studies have highlighted the drivers and barriers that facilitate and inhibit the shift to sustainable practice. Drivers have been defined in this context as any natural or human induced factor that directly or indirectly bring about change in an agricultural production system (Hazell and Wood 2008).

The attributes of sustainable practices such as risk, complexity, compatibility, trialability and observability play an important role in determining adoption of a practice along with demographic variables such as age, education, size of property and farm business and personal financial capacity (Cary et al. 2001). Public policy is a determinant with subsidies often seen as failing to appreciate environmental stewardship. Agricultural research has also largely focussed on solutions based on chemical use furthering unsustainable practices. Alternative marketing channels need to be created to bring sustainable farm produce closer to the end consumer for higher adoption levels to become a reality (Horrigan et al. 2002). Economic or regulatory pressures towards sustainability may also be exerted by international markets (Schleifer 2017).

Household income levels, dietary habits, climate change impacts and inefficiencies in supply chains influence acceptance of sustainable practices (Beddington et al. 2012). On studying the theories of adoption behaviour, it was found that profitability, and perceived nonmonetary costs of change were more significant than proximity of a prior adopter. Practices involving new technology depend on resource conditions. A distinction is also made between those who are unable to adopt because of reasons such as insufficient information, high cost of information, high complexity, short planning horizons and slow realisation of benefits, excess labour requirements, insufficient managerial skill and control over decision making versus those who are unwilling to adopt because of conflicting, inconsistent or irrelevant information, inappropriateness at current farm setting, high risk and conflicting beliefs (Caswell et al. 2001). The European Environment Agency has adopted the DPSIR (Driving Forces, Pressures, States, Impacts, Responses) framework to explain interactions between the environment and society.

Farmer unwillingness was further analysed and it was suggested that resistance or reluctance to adoption may have a logical basis (Vanclay and Lawrence 1994). Farmer behaviour, in particular, decision making, temporal dynamics and cross-scale and cross-level pressures need to be understood to appreciate the tendency to sustainable practices under situations of multiple pressures (Feola et al. 2015). Social dynamics between land owners and tenants and its influence on sustainable practices in rented farm-land was also studied (Carolan 2005). Farm plot characteristics was a greater influencer than farmer characteristics under conditions where practices involved easy to understand and low-cost technology (Arellanes and Lee 2003).

Short food supply chains such as farmers' markets, sales at farm, consumer cooperatives, community supported agriculture, internet sales and community gardening have been proposed as policy tools which will promote sustainable practices among farmers. Short supply chains are characterised by physical distances that have to be travelled by the produce and the social distances between producer and consumer and the opportunities for them to exchange information (Galli and Brunori 2013). Social network relationships among farmers determine diffusion of innovations and facilitates cooperation in agriculture (Levy and Lubell 2018).

While all the above studies focussed on the farm as a unit, one study recommended that it would be more advantageous to design integrated sustainable solutions for entire landscapes rather than to target individual farms. But, such an approach would require high levels of cooperation at different levels and would involve tougher implementation (Cobb et al. 1999). Current studies also indicate that simply modifying a few agricultural practices would be insufficient and that sustainable agriculture would require a radical redesign which does away with industrial production techniques such as monoculture or external input dependence. Ecological interdependence is a necessity to qualify for sustainability (Altieri et al. 2017). For those farmers who are open to technology upgradation, smart farming which involves the use of automation and robotic vehicles will disrupt conventional systems and promote sustainability (Walter et al. 2017).

Monitoring and Measuring Sustainability in Agriculture

Sustainability assessments aid farmers in understanding changes in yields and usage of resources which in turn could further incentivise farmers to adopt more sustainable practices. They help in setting baseline values and development of future action plans. Policymakers use sustainability assessments to understand sustainability levels present and to decide on further funding and research. Tracking of progress further ensures timely corrective action.

The lack of convergence of the definitions of sustainable agriculture implies that precise measurements of the degree of sustainability in practice may not be possible, however specific parameters may be used to decide if the farmer or business is moving towards sustainability and also for comparison between farms. Sustainability assessment has therefore acquired great significance in research and practice and many frameworks have been developed for the same. However, it should be noted that many of the tools and indicators would be context (time and location) specific and therefore cannot be generalised to every farm business. Going by the widely accepted three pillar approach, the indicators of sustainability fall under the classification of social, economic and ecological. They are also sometimes classified as being local, country or global scale (Hazell and Wood 2008) or field, farm, country and world level indicators.

Indicator selection depends on a number of criteria such as easy measurability, sensitivity to system stresses and integratability. Choice of tool is often dependant on attitude of users, ease of use, compatibility, transparency, complexity, data correctness, value in communication and effectiveness (De Mey et al. 2011). The metrics for measurement are based on issues such as nutrient use, pesticide use, water use, soil quality, farm management and farm finances.

Some indices such as the Ecological Footprint convert the impact of human activity into a common denominator which is the equivalent of biologically productive land and water needed for the activity (Wackernagel and Rees 1996). Life Cycle Assessment refers to a methodological framework that calculates the environmental impacts of the different stages of the life cycle of a product (Rebitzer et al. 2004). The Public Goods Tool is a means for assessing public goods from a farm through data collected from accounts, cropping records and farmer knowledge (Marchand et al. 2014).

Response-Inducing Sustainability Evaluation (RISE) is a farm level assessment tool that studies the current state and driving force of 12 indicators which includes energy, water, soil, cash flow and biodiversity and covers social, economic and environmental aspects (Häni et al. 2003).

Sustainability Assessment of Food and Agriculture Systems (SAFA) framework is one of several frameworks that seek to become universal in its application. The result of an iterative process, the framework was designed based on inputs from multiple stakeholders. In addition to the three pillars, SAFA also involves a fourth dimension of sustainability – good governance, and relies more on practice based indicators rather than performance based indicators (Food and Agriculture Organisation 2014).

The European Union co-funded a project to develop an analytical framework that is targeted at eco conservation through local agri-environmental programmes. Called AEMBAC (Agri-Environmental Measures for Biodiversity Assessment and Conservation), the project used a methodology that identified and investigated the state and pressures indicators of local agri systems and also the causal relationships between them (Simoncini and Milward 2004).

The Sustainable Agriculture Initiative (SAI) platform has created a computerised tool to help farmers quantify their sustainability efforts. Future objectives include permitting farmers to compare and track their performance, understanding their long-term impacts and giving data access to food and drink companies to track and compare the sustainable performance of their suppliers. Other computerised tools include Climate Yardstick, Environmental Yardstick for Pesticides, PRiME, Water Footprint Calculator, Gaia Biodiversity Yardstick, Fieldprint Calculator, Simpatica, Agri Yield Management System and Quickfire (SAI Platform and CLM 2014).

In addition to the varying indicators and metrics being used, differences in the methods of data collection add another level of complexity to sustainability measurements.

RESULTS AND DISCUSSION

Studies show that there is a wide divergence in the understanding of the concept of sustainable agriculture. The term has been described variously as a set of strategies, an ideology, as a motive for goal accomplishment or the ability to sustain. Such a wide diversity in definition could lead to incomplete or incorrect interpretation and implementation, impacting policy makers, farmers and academicians. Of all the different definitions of sustainability, the three pillar (social, economic and environmental) definition is widely accepted and has greatly influenced the concept of sustainable agriculture. Based on available literature, a comprehensive definition of Sustainable Agriculture would be the production of plant and animal products through practices and methods that encourage ecological interdependence, recycling and protection of natural resources leading to social well-being and continuous financial benefits.

The major events in the evolution of sustainable agriculture have been highlighted in Figure 1.

However, for the next phase of developments, a fundamental mental shift is required on the part of the producers and policy makers where the focus should be responsible financial profits. With increased ecological interdependence comes the opportunity to move away from single cropping, dependence on external inputs and a wider variety in plant and animal products leading to diversification of product range and the need to modify and engage the requisite marketing channels.

Several factors influence the uptake of sustainable practices in agriculture. Based on literature available, the drivers of sustainable agriculture may be broadly classified on the basis of

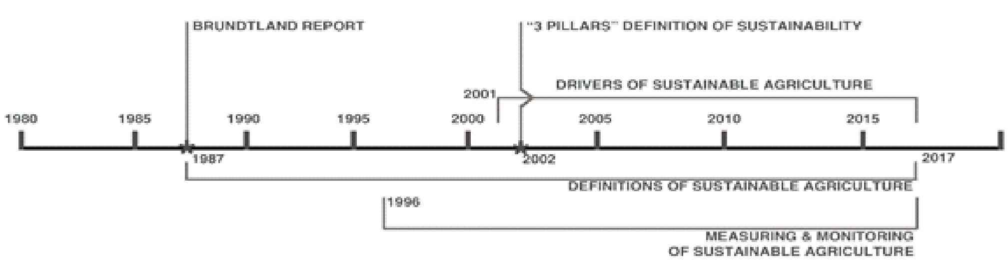

Fig. 1. Timeline of developments in sustainable agriculture
Source: Author

sustainable practice attributes, farmer demographics, business pressures and external/environmental pressures as depicted in Table 1.

Table 1: Classification of drivers of sustainable agriculture

Practice Attributes
- Trialability
- Risk
- Complexity
- Compatibility
- Observability

Business Pressures
- Marketing channel
- Customer's dietary habits
- Profitability
- Availability and cost of appropriate information

Demographics of Farmer
- Age
- Education
- Plot size and characteristics
- Financial capacity

External/Environmental Pressures
- Economic/regulatory pressure
- Climate change
- Social dynamics/community support

Quantifying sustainability performance has gained momentum in the last two decades. It is necessary to understand progress and make required course corrections. Frameworks have gradually drifted towards farmer's selection of indicators or metrics and method of data collection with the result that a rigorous comparison of farm businesses is not always possible. Newer frameworks rely on the use of information and communication technology to evaluate performance and to connect farmers with customers in the value chain. The points of divergence and commonalities between the different frameworks is shown in Figure 2.

CONCLUSION

Sustainability in agriculture has evolved significantly as a concept over the last few decades. While debates, discussions and extensive research have added to literature, there is no consensus in terms of definition. However, commonalities among the different explanations point toward sustainability in three aspects – social, economic and ecological. Newer research is trying to add to these aspects.

A lot of work has been done in development of frameworks and indicators for the measurement of agricultural sustainability. While some have focussed on single aspect measurement, many others are focussed on multiple aspects. Measurable metrics have been identified in some tools whereas certain frameworks encourage the user to identify metrics pertinent to their practice.

Drivers and barriers diagnosed at different levels aid policymakers in encouraging uptake of sustainable practices. These have been analysed at the level of the individual farm worker, the business and at the macro environmental level.

Agricultural sustainability has emerged as a wide interdisciplinary study, however, future research will need to focus on convergence of ideas and universal adoption of common mea-

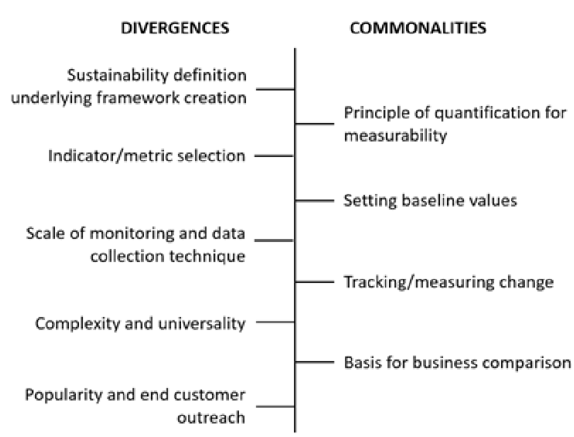

Fig. 2. Divergences and commonalities in sustainability frameworks
Source: Author

surement and monitoring mechanisms in order to capitalise on farm, regional, national and global level data.

RECOMMENDATIONS

Future work should target convergence of the concept of sustainable agriculture in order to establish globally accepted and recognised standards for measurement of performance. Standards will aid in rationalising operations and will provide a basis for further improvements and enhancements of existing practices. Establishing standards will also improve reliability and customer confidence in sustainable products and provide easier access to new markets.

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