Development of an Empirical Model of Sustainable Rice Farming: A Case Study from Three Rice-Growing Ecosystems in Bangladesh

Ranjan Roy, Ngai Weng Chan and Ruslan Rainis

Abstract: To facilitate sustainable agricultural development, this study developed a model of rice farming sustainability in Bangladesh and determined the key interventions for policy implementation. Data for the study were collected through a household survey and also via in-depth informal discussion with stakeholders. By constructing a composite indicator, path analysis results showed that major contributing sustainable rice farming indicators were land productivity, resources conserving practices and technologies and social and human capital building. Accordingly, we designed a model consisting of influential indicators, strategies and goals of dimensions, drivers of a conducive policy environment and cultural and ethical issues. The study concludes that existing models of sustainable agriculture are lacking in some important aspects and several interventions such as economic, institutional capacity building and policy making/reform are required for implementation of policy. This paper highlights the significance of an integrative model and the inclusion of the cultural values and ethical issues in fostering sustainable rice farming. Policy implications include: (i) invest on land productivity by adopting resource conservation and climate-smart practices and technologies, (ii) enhance social and human capital formation and (iii) take initiatives for economic intervention to smallholders.

Key words: Farming Sustainability Model · Sustainable Agriculture · Policy Implementation · Bangladesh

INTRODUCTION

“Business as usual” in agricultural production is increasingly not a fair option from the context of climate change and world’s state of food insecurity. Even with remarkable productivity gains in the last four decades, there are a billion people who go hungry [1], increasing risks from environmental hazards and chronic diseases [2] and continuous rural-to-urban migration throughout the world [3]. Unfortunately, this situation may worsen as intensifying pressure on natural resources to feed a burgeoning population, increasing food prices that experience shocks from market speculation and climatic disturbances all combine to reduce food availability. In the transition, sustainable rice farming keeps a crucial importance because of rice is the staple food for more than half of the world’s population and it has a historic relation with households and national food security, poverty alleviation, political stability, growth and development of Bangladesh and other agro-based countries.

Agriculture is the heart of the economy of Bangladesh and rice remains its lifeblood. Rice production employs almost 65% of the country’s entire labor force, provides annual 95% of the total food grain’s production and consumption and contributes to about 10% GDP [4]. According to BBS [5] rice production has increased about three-folds from 1970 to 2009. Despite the remarkable progress in production, it raises many concerns related to environmental pollution, agrobiodiversity extinction, health hazards (arsenic) and poverty in many regions. Several researchers [6, 7] reported that the present rice farming trends (input-based monoculture, highly intensive and mostly irrigated) and ecological consequences are not sustainable in the long term. Synthesised from these studies it can be summarised that rice farming is in a
threatened state due to continual degrading and declining water, land and biodiversity and created increasing top soil erosion, compactness, salinity and acidity. Moreover, growers have not economically and socially benefited due to high input price and comparatively lower rice market price. Another manifestation on unsustainability is the rice production system is the millions of malnourished people across the country.

Reasonably, agricultural sustainability, in particular, rice farming sustainability has attracted notable concerns from policy makers, academicians, researchers, civil societies and NGO workers. In fact, key questions of the country’s food security and poverty alleviation largely depends on sustainable rice production that needs contextual understanding of key driving forces, strategies, policies and strong political support [8]. Bangladesh’s National Agricultural policy 2012 mentioned that government is committed to the continuous development of agriculture and its sustainability to maintain food security. Similarly, national report on sustainable development (SD) acknowledges sustainable agriculture (SA) as one of the emerging issues beyond 2012 [9]. However, in both documents, there is no clear indication on how and on what pathways it promotes. Moreover, there is no well accepted model of SA and some are having lacked of important aspects of sustainability like good governance. We address these research gaps in the study.

Government has taken several initiatives, particularly, introducing many projects like crop diversification, integrated agricultural productivity and yield gap minimization at the regional and national level in order to empower farming community, maintain agri-environment, soil fertility and increase resource efficiency. Many organizations are working on the development issue of small and marginal growers to achieve the Millennium Development Goals. Additionally, several agricultural policies, strategies and programmes contribute to feeding country’s population over long time. However, the present problems are: increasing number of population with limited natural resource base and majority of growers are stallholders, poor, less educated and fully depend on agriculture. Studies show that major challenges of promoting SA are scarce natural resources, natural calamities and shortage of power. Moreover, financial, political and administrative problems are big hindrances of obtaining socio-economic development.

With the growing emphasis of SA for poverty alleviation and food security, we have made an attempt to design a model for achieving sustainable rice farming in Bangladesh, identifying essential indicators and strategies and goals of sustainability dimensions. Moreover, we determined the key interventions for better policy implementation, recognising the policy environment is a vital part of the model. Overall purpose of the study is to develop an inclusive model of

### Table 1: Characteristics of model of sustainable agriculture (SA).

<table>
<thead>
<tr>
<th>Model</th>
<th>Foundation</th>
<th>Feature</th>
<th>Strategy</th>
<th>Needs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing Asian countries SA [11]</td>
<td>Eco-friendly agriculture based on integrated management</td>
<td>Pro-nature, pro-poor, pro-women and pro-employment/livelihood oriented</td>
<td>Intensify agriculture by diversifying the production systems</td>
<td>Time- and locale-specific, demand-driven information and technology, participatory R and D</td>
</tr>
<tr>
<td>Twenty-first century SA [12]</td>
<td>Development of new Terra Preta sites (‘Terra Preta nova’)</td>
<td>Decrease the pressure on primary forests</td>
<td>Maintain biodiversity Maintaining biodiversity while mitigating both land degradation and climate change</td>
<td>Research on soil improvement, economic output and social acceptance</td>
</tr>
<tr>
<td>Coevolutionary [13]</td>
<td>Observations from the environmental history of agriculture</td>
<td>Ag dev as consisting of processes of coevolution with ecological and socio-economic systems</td>
<td>Strengthening local interaction and interconnect-edness in a rural-urban context</td>
<td>Indicators to direct actions and to facilitate communications</td>
</tr>
<tr>
<td>Emerging SA [14]</td>
<td>Intensification of crop yields</td>
<td>Create resource loops that operate on different levels the whole system</td>
<td>Crop rotation and interplanting</td>
<td>Collaboration with farming families</td>
</tr>
<tr>
<td>Sustainable farming practices [15]</td>
<td>Environment, economic, and socio-institutional dimensions</td>
<td>Identifying key aspects of SA and indicators</td>
<td>Sustainable management of inputs</td>
<td>Primarily social and human capital development</td>
</tr>
<tr>
<td>Assets-based [16]</td>
<td>Improving 5 types of asset is a central pathway to SA</td>
<td>It largely depends on the value of services flowing from the assets</td>
<td>Increase availability Increase availability and access to asset</td>
<td>Policies, processes and institutional support</td>
</tr>
</tbody>
</table>

Note: R and D: Research and development, Ag dev: Agricultural development, SA: sustainable agriculture.
sustainable rice farming. This is the contribution of this study and the findings of the study provide a significant policy input for sustainable agriculture development. This model is also replicable to other areas and crops to address the farming sustainability.

Early Attempts: Attempts have been made to develop the model of SA. A brief review is presented in Table 1. Based on the review, we can summarised that: (i) despite the importance of “cultural values” is recognised by the researchers [10] in promoting SD, almost all models overlooked the issue; (ii) ethical dilemmas were observed in setting goal, strategy and policy implication, (iii) model provided recipes for policy; however, driving forces for creating conducive policy environments were not explicitly considered, (iv) although good governance is vital in SA, a little importance was given on it in choosing factors and indicators and (v) the equal significance of three pillars for SD is well accepted, moreover, acknowledging contextual situation it may vary, which were not discussed, even considered. Besides these, some other models like three legs, competitive and living system models are merely described the comparative picture of three dimensions of sustainability. These models neither provided any indication of indicator determination nor policy actions. Whilst clearly existing models are different by foundation, feature, strategy and needs, there are an increasing awareness and academic debate on the need to develop an integrative hybrid model of SA that captures main issues of SD, as well as appropriate for achieving sustainable rice farming development.

MATERIALS AND METHODS

Indicator Generation: It observes a large amount of indicators of different disciplines and still indicator evolves. Researchers [17] also determined several shortcomings of indicator systems in diagnosing problems, providing timely information, contributing to decision making and advocating as well as identified that most of the weak points are related to their construction methodology. In this study, we adopted a participatory approach that comprised four stages such as (i) establish study context, (ii) information exploration, gathering and brainstorming by discussion with academicians, literature review and conducting online survey, (iii) indicator validation by grower’s focus group discussion (FGD) and (iv) indicator development. Following the four stages we generated 15 essential indicators (Table 3 which justifies multistakeholders involvement employing participatory approach. For more detail methodological explanations the work of Roy et al. [18] can be consulted.

Study Area and Data Collection: This study was conducted in three major rice-growing ecosystems, namely, irrigated, rainfed lowland and upland in Bangladesh. Based on these ecosystems’ districts, sub-districts and villages were selected by applying a multistage random sampling technique (Fig. 1). Accordingly, we selected 15 villages from the three sub-districts, namely, Pirganj, Dinajpur Sadar and Natore Sadar that represents irrigated, rainfed lowland and upland ecosystems respectively. A total of 386 households from 15 villages were surveyed using

Fig. 1: Location of the study area in Bangladesh.
structured questionnaires. Employing simple random sampling method 26 households were selected from each village considering the proportional size of farms like large, medium and small. Details information of growers on income; employment; pest, disease and weed management; crop varieties grown; organizational involvement; knowledge and skill; and public services provision was collected. After collecting all information, we checked, cross checked, tabulated and prepared a completed data set. Descriptive statistics were presented in Table 3. It was observed that the distribution of farmers on the basis of farm size was representative of the national distribution. Moreover, we conducted in-depth informal discussions with the total 105 extension personnel, NGO workers, local leaders, input sellers, civil-society members, researchers, growers and decision makers to seek precise information on identifying interventions for creating a favourable environment for policy implementation of sustainable rice farming. In addition, supplementary information was collected from concerned agricultural offices.

Determine key Indicators by Constructing a Composite Indicator (CI): Reductionist approach is getting popular as a tool for supporting decision makers. The major attributes of CI are user friendliness, effective and efficient tools for public communication, innovative approach to measure complex and vague issues and comparatively easier in policy priority setting. In this study, we developed a CI following the methodology provided by the OECD [19]. A brief overview of steps, objectives and methods for building a CI is presented in Table 2. Data quality is a vital part for developing a meaningful and communicative CI. For that purpose, we conducted several data screening tests, for example, outlier checking (by log and reverse score transformations) and normality (estimating skewness) of the data set [20]. Moreover, we conducted Pearson correlation in order to observe the interrelationship and multicollinearity among indicators and run principle component analysis to see the multidimensionality [21]. These analyses helped us to examine the overall structure and data suitability for the subsequent methodological choices.

Then we administered the major three stages of CI construction, namely, normalization, weighting and aggregation. We applied max-min method for normalization (equation 1), factor analysis for weighting [22], arithmetic average (equation 2) to combine indicators within dimension and geometric average (equation 3) to combine the dimensions. After developing CI, again we run correlation between indicator and index value to measure internal consistency of the index [23]. Finally, confirmatory path analysis was used to determine the most contributed indicators by calculating the direct and indirect effect of an indicator to the index. Path analysis is a straightforward extension of multiple regressions (with correlation matrix input), where index value used as the criterion and indicators treated as the predictors.

\[ l_i = \frac{x - \min(x)}{\max(x) - \min(x)} \] \hspace{1cm} (1)

\[ CI = \sum_{i=1}^{n} l_iw_i \] \hspace{1cm} (2)

\[ CI = \prod_{i=1}^{n} l_i^{w_i} \] \hspace{1cm} (3)

Where, \( l_i \) is the normalised value of individual indicator, \( x \) is the raw value of individual indicator, \( \max(x) \) and \( \min(x) \) are the maximum and minimum value of \( x \), \( CI \) is the composite indicator of sustainable rice farming and \( w_i \) is the weight associated to individual indicator.

<table>
<thead>
<tr>
<th>Major step</th>
<th>Objective and method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developing theoretical framework</td>
<td>To lay the foundation of CI.</td>
</tr>
<tr>
<td>Data selection and treatment</td>
<td>To ensure available and quality of data. Data screening tests, like outlier and normality checking.</td>
</tr>
<tr>
<td>Imputation of missing data</td>
<td>To provide a complete dataset. Use mean value for single or multiple imputation.</td>
</tr>
<tr>
<td>Multivariate analysis</td>
<td>To examine data structure and suitability of further methodological decisions.</td>
</tr>
<tr>
<td>Normalisation</td>
<td>Correlation and principal component analysis (PCA).</td>
</tr>
<tr>
<td>Weighting and aggregation</td>
<td>Factor analysis and linear and geometric aggregation.</td>
</tr>
<tr>
<td>Construction of index</td>
<td>To develop a meaningful index following above steps.</td>
</tr>
<tr>
<td>Internal consistency and</td>
<td>To observe how far a CI is internally sound, consistent and robust.</td>
</tr>
<tr>
<td>robustness checking</td>
<td>Correlation, PCA and dominance analysis (by path analysis).</td>
</tr>
<tr>
<td>Result, discussion and presentation</td>
<td>To visualise of the results in an effective way.</td>
</tr>
</tbody>
</table>
RESULTS

Table 3 presents the contribution of indicators and pillars to the CI. It was observed that highly contributed (about 8%) indicators were land productivity, resource-conserving practices and technologies, net-farm income, human and social capital. About 80% of indicators influenced the CI by more than 5% those were included in the model. Relatively, considering the added value of indicator’s social dimension was contributed by 35% to the index followed by economic (33%) and environmental dimension (32%). Fig. 2 presents the model for promoting rice farming sustainability that consist of a number of indicators (within outer cycle), strategy (in arrow) and goals of dimensions (in between lines). The strategy and goal definition was deduced from observation, discussion with stakeholders and literature review. The indicator closer to the inner circle, more influences to the index were calculated. The goal of social dimension assumed society’s well-being and contributed indicators were capital formation (human and social), good governance (public participation, accountability of public employees) and equity. Likewise, growers profit making trends were observed by realizing higher yield, variety’s non-farm sources of income and achieving net farm return to achieve economic viability as well as to foster sustainability. Moreover, promoting a healthy agroecosystem is a desired goal of environmentalists and that was significantly influenced by adopting diverse crops, sustainable approaches, integrated nutrient, pest and disease management, which were plausibly conserved and enhanced biodiversity, land and water resources of farmland.

DISCUSSIONS

In discussion authors discuss the justification of the model, specifically present indicator’s characterizations and practical aspects related to the studying area. Moreover, background, component and significance of the dimensions are described. In the model, indicator systems are embedded within a flexible planning process as it closely links with contextual and situational perspectives that can be changed over time. On the contrary, three pillars of SA are well-established and recognised. Strategies and goals of the pillar are derived from survey experience and past literatures. However, all these indicators, pillars, strategies and goals are embedded within the policy environment that needs to be culturally appropriate and ethically legitimate.

Social Pillar: Social sustainability is an imprecise and multifaceted concept and there is no single most common definition of it. The pluralism of the thematic areas of social sustainability makes the term complex and operationally elusive. Consistent with OECD [24], our result showed that the dominancy of this dimension among others. The probable justification might be the insensible socio-economic picture

Table 3: Definition, measurement, descriptive statistics and influence of indicators on the composite indicator (CI).

<table>
<thead>
<tr>
<th>Pillar and indicator</th>
<th>Mean</th>
<th>Std. deviation</th>
<th>Skewness</th>
<th>Kurtosis</th>
<th>Effect (%) of indicator on CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economical</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32.35</td>
</tr>
<tr>
<td>Land productivity</td>
<td>5111.98</td>
<td>1082.02</td>
<td>0.03</td>
<td>-0.45</td>
<td>8.91</td>
</tr>
<tr>
<td>Net farm income</td>
<td>10902.22</td>
<td>7310.2</td>
<td>0.23</td>
<td>-0.45</td>
<td>7.90</td>
</tr>
<tr>
<td>Input-self-sufficiency</td>
<td>0.54</td>
<td>0.07</td>
<td>0.02</td>
<td>-0.74</td>
<td>4.49</td>
</tr>
<tr>
<td>Production cost</td>
<td>65217.47</td>
<td>42101.39</td>
<td>0.82</td>
<td>0.94</td>
<td>4.00</td>
</tr>
<tr>
<td>Non-farm employment</td>
<td>2.43</td>
<td>1.54</td>
<td>-0.48</td>
<td>-0.98</td>
<td>7.05</td>
</tr>
<tr>
<td>Ecological</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>32.70</td>
</tr>
<tr>
<td>Nutrient management</td>
<td>13.56</td>
<td>3.31</td>
<td>0.37</td>
<td>0.19</td>
<td>7.33</td>
</tr>
<tr>
<td>Use of sustainable practices and technologies</td>
<td>36.12</td>
<td>4.29</td>
<td>0.26</td>
<td>-0.34</td>
<td>8.72</td>
</tr>
<tr>
<td>Crop diversification</td>
<td>0.62</td>
<td>0.11</td>
<td>0.15</td>
<td>-0.72</td>
<td>6.71</td>
</tr>
<tr>
<td>Pest and diseases management</td>
<td>9.10</td>
<td>1.22</td>
<td>0.07</td>
<td>-0.84</td>
<td>6.94</td>
</tr>
<tr>
<td>Weed management</td>
<td>2.90</td>
<td>1.20</td>
<td>0.04</td>
<td>-0.37</td>
<td>3.00</td>
</tr>
<tr>
<td>Socio-political</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>34.95</td>
</tr>
<tr>
<td>Human capital</td>
<td>55.19</td>
<td>9.19</td>
<td>-0.09</td>
<td>-0.67</td>
<td>8.42</td>
</tr>
<tr>
<td>Public participation in decision making</td>
<td>2.30</td>
<td>1.80</td>
<td>0.32</td>
<td>0.61</td>
<td>6.55</td>
</tr>
<tr>
<td>Accountability of public employees</td>
<td>1.90</td>
<td>0.92</td>
<td>-0.29</td>
<td>0.49</td>
<td>6.17</td>
</tr>
<tr>
<td>Social capital</td>
<td>20.69</td>
<td>3.84</td>
<td>0.30</td>
<td>-0.90</td>
<td>7.89</td>
</tr>
<tr>
<td>Equity</td>
<td>32.54</td>
<td>3.317</td>
<td>-0.25</td>
<td>-0.68</td>
<td>5.92</td>
</tr>
</tbody>
</table>
Fig. 2: Rice farming sustainability model in Bangladesh.

(primarily, rural poverty, no source of income other than agriculture and less education of growers’) of rice farmer raises more concerns from social issues.

Capacity development is an inevitable asset to tackle emerging problem. By building capacity it is easier to reach root of the problem and every single farmer can play a significant role as a grower, leader as well as a practitioner. Similarly, institutional, market and society’s capacity development can act as a catalyst for managing and promoting individual and social well being. Discussion revealed that capacity building was a prime strategy to solve farming problems and to realise the more economic benefits.

Social and Human Capital: Social capital is a fundamental ingredient for sustainable community. Its key elements are mutual interest, collaborations and partnerships, embedded shared purposes, develop and nurture relationships and reciprocity through trust. It consists of two complementary components: structural (organizational networks) and cognitive (norms, values, attitudes and beliefs that emerge from community gathering) social capital. MacGillivary [25] states that social capital is “creative trust and represents the stock of networks, stakeholder relationships and shared rules that help organizations and their surrounding communities work more effectively.” Discussion with farmers revealed that social capital enhanced grower’s physical and human capital substantially.

Human capital is an essential constituent of social sustainability, which means the total capability residing within an individual, based on his or her stock of knowledge, skills, experience, health and nutrition [26]. Human capital is crucial for several reasons, mainly; it develops an educated and skilled generation of growers with up-to-date knowledge, technical skill, innovation and sound understanding of agricultural problems so that they can interact with innovative farming approaches and modern technologies to cope with agrarian risks, achieving food, fuel, environmental security and better livelihoods. Grower’s human capital can be improved by increasing access to education, training programmes and services such as farmers’ field schools, IPM club and extension activities. It was observed that farmer’s human capital like leadership, motivational and organizational skills were significant to make resources available, accessible and valuable.

Equity: Equity is a necessary part of inclusive development, which comes from the idea of moral equality in terms of balance life chances, equilibrium concern for people’s needs and meritocracy. There is a growing
recognition that equity is essential for SD, for example; UNDP [27] empirically shows that how inequalities in human development amplify environmental degradation and how ecological degradation intensifies inequality through adverse impacts on the poor people. There are considerable inequities are found in the study areas and people’s access to services, resources and institutions are influenced by power balances in the economic, communal and governmental spheres, that often lead to poverty, resource degradation, public exclusion and unsustainable development. Therefore, several measures, specifically, providing public services to all categories of growers, targeted action for small and marginal groups, social protection measure and land reform are important for promoting equity to address the political economy of change and long-term development at local, regional, national and global scales for the present and future generations.

Good Governance: Governance is simply an act or manner of governing, including policy making and implementation. However, good governance refers to efficient allocation of public goods of necessary quality to its citizens and management of resources to respond to collective problems [28]. It is imperative for poverty alleviation, address inequality and sustained economic growth. Synthesis from this literature shows that common elements of governance are community participation, accountability, transparency and institutions. Among them local participation and accountability of public official is pronounced to a great extent for promoting grower’s social sustainability.

In recent years, public participation has become a critical concept in SD. Effective participation leads to greater self-awareness, confidence, social learning, mediating conflicts, collaborative action, better policy decision and implementation. Moreover, it is a key route for people’s empowerment, accountability and transparency. The Johannesburg World Summit Declaration recognised that broad-based community participation is central for policy formulation, decision-making and implementation at all levels, particularly, women participation is inevitable in all aspects and at all levels relating to SA and food security [29]. However, promoting interactive and effective participation is harder than the term discussed in the different forums of science, which raises several criticisms too, as Cooke and Kothari [30] opined that participation being the “new tyranny” in development work.

Accountability is one of the cornerstones of good governance that allows public employees answerable for their behaviour, actions and responses. Participation is often related to accountability, but it is often not so. It facilitates better public services, efficient resource use, transparent and corruption free financial management and evidence-based policy formulation and implementation. Researchers show poor accountability reduce the state’s credibility as an economic partner [31] and compromise demand-driven agricultural advisory services [32] as well as the ability to monitor the environment [33]. It is observed that achieving accountability in public services in the rural areas remain several challenges. However, a strong political will and decentralised institutional mechanism is required.

Economic Pillar: Despite SA has been achieved its initial credibility as an economic issue from the public policy agenda, the ecological issue gains prominence in the context of environmental turmoil. This dimension is one of the central parts of farming sustainability. Hosseini et al. [34] reported that economics is the most important factor of SA. In particular, it relates to the responsible and efficient use of resources to establish the long-term profitable business. The economic sustainability is closely linked with ecological and social sustainability because of its values is derived from the natural and communal resources. In current times, there has been increasing attention to the economic sustainability of farm and business around the world; the reasons are two-folds: the recent financial meltdown and its relationship with natural resources, which are apparently vulnerable due to global warming.

Economic viability is a goal, as well as essential condition for SA and food systems. It is a broad objective that can be achieved by a variety of means, including but not limited to sustainability-compatible production strategy, favorable agricultural policy and environment, rural infrastructure and market accessibility. However, all of these elements facilitate directly and indirectly to grower’s net profit making. From observation, it can be said that enhancing its viability of farm producers is the prime component for providing the means of conserving as well as improving ecological and social sustainability in the study areas.

Land Productivity: In the context of burgeoning population growth and declining agricultural land for increased non-agricultural purposes, raising land
productivity is one of a promising solution to feed the extended population. Obviously, this productivity has to be in a socially responsible and ecologically sound way; otherwise these initiatives will aggravate the existing problems. This issue is stressed vigorously by several organizations and researchers that land productivity is the main pathway for poverty alleviation, achieving food security and socio-economic development [35]. Numerous strategies are suggested to do so such as crop diversification, ecological agriculture, integrated farming, promote appropriate technologies, providing demand-led extension services, improve the quality of agricultural inputs and financial incentives. Simultaneously, it is also important to take necessary initiatives to curb the impact of climate vulnerability and natural disaster.

**Net Farm Return:** Net farm return is a financial term that describes and measures the farming profitability, a well-accepted indicator for measuring economic viability. First, a farm has to be profitable with taking risk to be sustainable. Beets [36] reported that “inclusive development involves maximizing the net benefits from economic development, subject to maintaining the services and quality of natural resources over time.” Generally, growers equated a farm having more net return is more sustainable. In case of irrigated rice growers, they presume “more investment and more net return.” Many factors influence this returns, namely, the prices of input and output, market price fluctuations, locational factor, weather and communication facilities.

**Non-Farm Employment:** In Bangladesh, majorities of the farmers are marginal to smallholders and it is observed that farmer’s socio-economic condition in particular unemployment in the lean season, lack of sufficiency of cash flow in the peak season, thin and uncompetitive markets and inadequate financial services are major hindrances of maintaining higher production. Due to shortage of hard cash, poor growers cannot purchase necessary inputs, which hampers farming productivity and profitability. Consequently, two things are happened like young generation loss their interest in farming and rural to urban and international migration. Losch et al. [37] examined that local non-farm employment, and self-employment can play key roles not only in well functioning agricultural production, food markets and promoting food security but also ensure the livelihood portfolio of wealthier households, better in vulnerability adaptation and risk mitigation. Similarly, country’s PRSP and National Agricultural policy 2010 underscores the significance of non-farm employment in achieving sustainable socio-economic development.

**Environmental Pillar:** Historically, environmental aspects have a strong link with sustainability issue and its prominence is evolving consecutively. A landmark contribution of the three seminal publications is widely acknowledged, namely, (i) “Silent spring” [38] first identified chlorinated pesticides as a major pollutant, (ii) “Limits to Growth” [39] reported significant influence of worldwide ecological constraints on global development in the twenty-first century and (iii) “Brundtland report” [40] highlighted three fundamental components to SD such as environmental protection, economic growth and social equity. The latter is stressed necessary actions for avoiding natural resource’s degradation, over-exploitation and pollution from all sectors and established environmental pillar as a core part of SD. Moreover, in recent times of more tangible impacts of climate change has set the issue at the forefront of policy agenda of national and international organizations.

Researchers’ defined environmentally sustainable agrarian systems based on their own their theoretical foundation. However, a converging issue of an agricultural system should be “resource conserving and enhancing” for fostering “sound ecosystem” is emerged from the findings from the study. From our perspective, ecologically sustainable farming is a balanced, resilient and adaptive management of natural and man-made capitals, which conserves and enhances resources to build a healthy agroecosystem over the long time.

**Resource Conserving Practices and Technologies:** Now it is established that agriculture is a significant source of environmental harm, particularly rice farming is a big source of methane gas emissions. Moreover, agricultural production has to be increased to feed increasing population. Plausibly, this will pose further challenges on ecosystem to continue productivity and its ability. Therefore, this is essentially important to give emphasis on resource conserving practices, namely, alternative wetting and drying irrigation, conservation agriculture, mixed cropping and technologies like IPM, deep urea placement, dram seeder at the centre of policy agenda for sustainable production. These practices and technologies do not have adverse effects on environmental good and services, leading to raise input use efficiency, provide ecological benefits and improving
productivity and grower’s decent livelihood. There is an impressive amount of literature suggest that these approaches and technologies are potential for enhancing productivity [41], superior than conventional technologies in terms of cost saving and more efficient use of inputs and poor farm households benefit from their adoption [42]. It is uncertain that these practices and technologies can meet future food demands, however, can substantially contribute to curb the present agricultural crossroads.

**Crop Diversification:** Crop diversification is a fair strategy to maximise the use of natural and manufactured resources that enhance agricultural productivity and growth, maintaining a balance of major and minor crops, soil fertility and biological species diversity. A diversification in crop cultivation provides growers several viable options for year-long income, employment, poverty alleviation and food security. Many studies showed that multidimensional importance of crop diversification, for example, it influences production [43], is an effective means for resilient building and crop risk management [44]. Moreover, Lin [45] conducted a useful review on how resilience in agriculture can be improved through crop diversification and its potential benefits to increase production stability, climate-change buffering, pests and disease suppression.

**Integrated Management of Nutrient, Pest and Diseases:** Adopting an integrated approach is inevitable for the SA of better productivity, conserve ecosystem ability and sustainability. The basic tenets of integrated plant nutrient managements are: use combinations of organic, biological and mineral fertilisers; apply on-farm and off-farm vegetable and animal waste through recycling; and provide nutrients on a cropping-system/rotation basis. However, external nutrients are used in a rational way that is yield-targeted, soil- and site-specific to reduce chemical’s volatilization and runoff. There is much past evidence [46] that integrated management of pest, disease and nutrient improves the biological, physical and hydrological properties of soil, enhance farm productivity and soil fertility, increase systems efficiency, resiliency and reduce emissions.

Integrated methods of managing pests and diseases are an effective and ecologically-sound approach that encourages the use in a combination of common-sense practices (crop rotations, traps, bio-insecticides, pest-resistant varieties) and minimises the use of chemical controls. Usually, pest incidence is monitored and action is taken just when damage exceeds tolerable limits and chemical methods are only applied when other options are ineffective. An effective disease management is closely aligned with the goal of pest management.

**Policy Environments:** Based on discussions, we determined three policy niche areas, namely, economic interventions, institutional capacity building and policy formulation/reform where government investment is urgent. Overall, a concerted effort of government, farmers and organizations are important to create a favorable environment for policy decision implementation.

**Economic Interventions:** It realised that various economic interventions were useful in adopting SA practices and technologies. Considering the socio-economic condition of the majority of farmers, several strategies for increasing employment, investment on rural economy, local infrastructure and markets are crucial for economic growth. Many promising measures for farmers such as adapting micro finance, reforming public agricultural banks, providing monetary services through self-help groups, financing through interlinked agents, financial cooperatives and transitional support can act as a great complement for sustainable farming. For that reasons it is not only important to ensure good, efficient and effective economic management but also need to strengthen the economic side of good governance. Moreover, political and macroeconomic stability, convenient fiscal and monetary policies, reliance and sound management on market forces are significant. Input subsidies on fertiliser, irrigation and technology contribute significantly in different countries. However, these should be revamped cautiously; otherwise these can inspire excessive input use, groundwater depletion and introduction of monoculture.

**Institutional Capacity Building:** Institutional capacity building is fundamental to ensure better governance. Good governance and SD are two sides of the sustainable agriculture coin. In essence, capacity building is about people - who provide public services and goods to people; manage organizations at different levels and responsible for policy making, analysis and implementation. Broadly, this includes ministries, department of agricultural extension, empowering producer organizations, NGOs and civil societies. Capacity building is necessary to cope with emerging
challenges by enhancing administrative capacity and decentralization, expending rural and financial services and improving the efficiency of public services and spending. There is evidence that most of the agricultural-based countries have much been lacking in institutional capacity building and it is admittedly essential to promote SA [8]. It is important to invest in invigorating the strength of public and private organizations, social and human-resource development, improving financial structure and providing a free, fair and stable political atmosphere. It is an ongoing process that requires an immaculate planning, programming and initiatives. However, these have to reflect explicitly the changes, need and aspirations of people as well as new ideas, high-yielding crop varieties and innovative technologies.

Policy Formulation/Reform: In sustainable farming, policy formulation should be given emphasis on solid understanding of the drivers of better management of natural resources. Simultaneously, it has to meet triple objectives of achieving food security, maintaining environmental sustainability and generating economic growth and opportunity. With a view to facilitate convergence on policy directions the process needs to be participative and evidence-based, ensuring effective dialogue and contribution of key stakeholders, particularly those are responsible for policy making, analyzing and implementation and those who are affected by the policy. Its generic strategies are community empowerment, improve access to public goods and services, better livelihoods, enhance competitiveness and supporting pro-poor investment. Similarly, agricultural, rural development, land, price, trade policy reform is a major pillar of the fundamental economic reforms. Policy reforms as a means to correct economic market failures, stimulate technological investment and provide an incentive to disadvantaged groups, leading to obtain far greater and more enduring results to socio-economic development. However, policy formulation or reform always faces administrative, political and financial challenges that require effective leadership at each stage of the process and it has to be evidence-based and linked to the better future for all.

Cultural and Ethical Values: Recently, an increasing attention has been observed towards the significance of cultural values in SD. Researchers proposed that culture should be viewed as: fourth pillar, component of social dimension or core element of socio-economic development. This issue is not considering adequately in sustainability discourse due to its diverse opinions in conceptualizations and characterizations. It usually refers to particular values, beliefs, customs, traditions and heritage that affirm identity and diversity. The World Commission on Culture and Development defined culture as “ways of living together”. Similarly, social science discipline configures culture as a “whole way of life.” However, there is a substantial consensus that the contribution of cultural values in promoting SA [10], which fosters growers’ rural revitalization, community norms and trust, local organizations and networks and improved livelihoods by strengthening community participation, partnerships, capital and community cohesion. UNESCO [47] has recognised that “unless economic development has a cultural basis it can never lead to truly lasting development.” Tibbs [48] showed how change in cultural values could contribute to achieve sustainability and explored the timing of a possible transition.

SD has an inextricable relationship with ethics. The Brundtland report illustrated the two major ethical aspects: meeting people’s needs and a commitment to future generations. An ethic in SA is about choices of farmers and others who are directly and indirectly engaged in agriculture. It is established that in the present context, the utilitarian approach is not enough to take decisions about agricultural approaches and technologies that do not reduce hunger and poverty as well as assure access to all farmers and environment-friendly. More importantly, policy implications have to signify the ethical values in enhancing producer’s natural resource management, access to resources and services, gender equality and equity, public participation and accountability for promoting sustainable farming.

CONCLUSIONS

We conclude that existing models of sustainable agriculture have some lacking of issues and an integrative model is significant for achieving it. A good model should have a clear indication of essential indicators, strategy and goal definition of dimension, drivers for conducive policy environment and cultural and ethical issues. Our overall evaluations are: (i) developing a representative set of indicators is crucial for promoting sustainable agriculture, (ii) the representation of cultural values and ethical issues are significant in achieving sustainable agricultural development and (iii) determination of recipes
for policy implications are not enough, rather investment is needed for creating favourable policy environment. The contribution of cultural and ethical issues is not empirically apprehended in the model. This is a limitation of this research. Sector wise investigation on policy intervention for sustainable development is a potential issue for future research. The study develops a model which is applicable for management, monitoring and assessment of sustainable rice farming in Bangladesh, as well as replicable to other crops and areas. Policies should emphasise: (i) increasing land productivity through the development of high yielding rice varieties, quality seed, accessibility and availability of agricultural inputs, credit and market; (ii) adopting ecosystem approaches, climate-smart practices, integrated farming approaches and modern technologies; (iii) capital formation by increasing and accessing demand-driven extension services, non-formal education and patronizing local institutions and networks; (iv) provisioning economic interventions for smallholders, women growers and rural youths. Creating a favourable environment for better policy implementation is a fair strategy for farming sustainability transitions.

ACKNOWLEDGEMENTS

We would like to extend our sincere gratitude to the all respondents of survey and discussion for their valuable time and input. Financial support from Universiti Sains Malaysia, Penang, Malaysia is gratefully acknowledged.

REFERENCES