An 'innovation-cycle framework' of integrated agricultural knowledge system and innovation for improving farmers'climate change adaptation and risk mitigation capacities

A case of Bangladesh

Rahman, Md Zillur

Published in:
Journal of Agricultural Extension and Rural Development

DOI:
10.5897/JAERD2014. 0653

Publication date:
2015

Document Version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Rahman, M. Z. (2015). An 'innovation-cycle framework' of integrated agricultural knowledge system and innovation for improving farmers'climate change adaptation and risk mitigation capacities: A case of Bangladesh. *Journal of Agricultural Extension and Rural Development*, *Vol.7*(7), 213-220. [5DFF69954172]. https://doi.org/10.5897/JAERD2014. 0653

academicJournals

Vol.7(7), pp. 213-220, July, 2015
DOI: 10.5897/JAERD2014. 0653
Articles Number: 5DFF69954172
ISSN 2141-2154

http://www.academicjournals.org/JAERD

Journal of Agricultural Extension and Rural Development

Full Length Research Paper

An 'innovation-cycle framework' of integrated agricultural knowledge system and innovation for improving farmers' climate change adaptation and risk mitigation capacities: A case of Bangladesh

Md Zillur Rahman

Sustainable Working Life Studies Group, Department of Environment, Social and Spatial Change (ENSPAC) Roskilde University Universitetsvej 1, DK-4000, Roskilde, Denmark.

Received 1 November, 2014; Accepted 29 April, 2015

The main objective of this paper is to present a new 'innovation-cycle' integrated conceptual framework of 'TVET-adaptive AKSI' (TVET: Technical and Vocational Education and Training; AKSI: Agricultural Knowledge System and Innovation). Thus the aim here is to discuss from existing body of literature of how 'TVET-adaptive AKSI' can be the 'Next Frontier of Green Innovation' and adaptation strategy to improve agricultural-based producers' understanding of 'risk perception and mitigation' (a case of Bangladesh is considered). Given the present state of producers' risks perceptions and the increased risks of safe agricultural food production, sustainable environment and health, it will be unprecedented challenges due to increasing demand for safe food supply for future growing population in Bangladesh. Studies show that producers (farmers) are still lagging behind with lack of necessary capacities including shortage of adequate knowledge of understanding in both 'environmental' and 'health' risks, which are contributing to excessive use of pesticides, fertilizers and agrochemicals for agricultural production, mixing of prohibited or hazardous chemicals with foods and foodstuffs for food adulteration, post-harvest preservation, and processing without being sufficiently aware of health and environmental consequences. To address the issue, very little investigations were done to understand how producers' perception and ignorance of risks are interconnected to the ways of their risky behaviour. Thus the aim of this paper is to explore existing literature to draw an understanding by developing a 'conceptual framework' about the urgent need of future 'Game Changer' strategy (e.g. Next Frontier of Green Innovation) for the safety and security of rapidly growing population by tackling the challenges of sustainable agricultural and safe food production in Bangladesh.

Key words: Agricultural knowledge system, Bangladesh, climate change adaptation, conceptual framework, next frontier of green innovation, networks, risk perception and ignorance, risk mitigation, Technical and Vocational Education and Training (TVET).

INTRODUCTION

In global context, the impacts of climate change are posing huge challenges for agricultural sustainability (IPCC, 2014; Barros et al., 2015; Chen et al., 2015; Wood and Mendelsohn, 2015) and thus adaptation (Gerlitz et al., 2014; Ngugi et al., 2015; Niles et al., 2015; Truelove et al., 2015; Waongo et al., 2015) and mitigation (Havlík et al., 2014; Makkonen et al., 2015; Gelfand and Robertson, 2015; Domínguez and Fellmann, 2015) have become the core issues in many countries (Ipcc, 2014; Noble et al., 2014; Nam et al., 2015). Despite many initiatives, adaptation of agricultural innovations by smallholder farmers specially in developing countries seems to be slow (Meijer et al., 2015; Berkhout et al., 2015), this is due to farmers' proper knowledge gap about the risks of climate change (Rahman, 2013; Banerjee, 2015; Kalafatis et al., 2015). In relation to Bangladesh, the impacts of climate change and human induced unplanned development activities are posing a huge challenge to millions of rural people's livelihoods (Hijioka et al., 2014; Ipcc, 2014; Amin et al., 2015; Mishra et al., 2015). For instance, in the context of human security, people are facing serious water pollutions and scarcity, heat stress, seasonal food shortage for low agricultural productivity (Adger et al., 2014; Hellberg and Chu, 2015; Kamruzzaman et al., 2015). To address these challenges, there has been huge change of agricultural knowledge systems during last decade. Main driving forces for such changes are the dynamic structure of supply and demand of agricultural markets such as new types of products and services for growing population (Ahmed et al., 2014; Jordan, 2014; Hassan, 2015).

The agricultural sector provides livelihoods to more than two-thirds of the population of Bangladesh and employs about 62% of the total population (Biswas et al., 2001; Rasul and Thapa, 2004; Rashid et al., 2014). To address the issues of agricultural-based safety and environmental adaptation, Government of Bangladesh started to take many initiatives through agricultural extension programmes including harnessing technology more effectively since many years ago (Islam and Grönlund, 2007; Habiba et al., 2011; Islam et al., 2015; Rahman and Siddiquee, 2015). For example, for the last 40 years, popular agriculture based TV programmes '*Mati-o-Manush'*, and *'Nodi o Jibon*' have been trusted by farmers (Ahmed, 2010; Uddin and Qijie, 2013).

Other major initiatives include the World Bank's advocacy of the Training and Visit (T and V) approach to extension in the 1970s, 'Agricultural Support Services Project (ASSP, 1992-1999)', 'Agricultural Services and Innovation and Reform Project (ASIRP, 1999-2002)', 'Thana Cereal Technology Transfer and Identification Project (TCTTI, 1995-2000), Integrated Soil Fertility and Fertilizer Management Project (SFFP, 1993-2000)', 'Agricultural Diversification and Intensification Project (ADIP, 1997-2004)', and latest 'e-KRISHI Vision 2025'. According to Ahmed (2010), agricultural extension workers were specially trained to assist farmers in adopting new technologies for High Yielding Varieties (HYVs).

Despite of various technology-based initiatives, evidences show that farmers in rural areas in Bangladesh are lagging behind with lack of necessary capacities for understanding about the impacts of climate change and agricultural-based risks (Chen et al., 2004; Parvez et al., 2006; Rahman, 2013; Ahmed et al., 2015). The impacts of climate change such as drought, floods are understood by high numbers of local producers as 'Divine Retribution' or 'Natural matters' (Paul and Routray, 2011; Rahman, 2013). All of these are contributing to increase the risks of climate change and environmental adaptation as well as posing threats to human health and livelihoods. The lack of necessary capacities is further contributing to excessive use of pesticides, fertilizers and agrochemicals for agricultural production, mixing or adding of prohibited or hazardous chemicals to foods and foodstuffs for food adulteration, post-harvest preservation, and processing (Wooster et al., 2005; Hossain et al., 2008; Ali, 2013; Rahman, 2014; Robson, 2014; Hassan, 2015).

Overuse of pesticides and chemicals and their impact are highlighted in many researches (Rahman, 2003; Isin and Yildirim, 2007; Pretty, 2008; Heong et al., 2015). It is alarming that in Bangladesh majority of farmers are not trained in pesticides use or handling fertilizers or spraying preservatives, and most of them openly admit to using little or no protective measures while applying pesticides (Dasgupta et a., 2005; Hassan, 2015). This results in increased health and environmental risks due to contamination of water, loss of biodiversity and deterioration of soil quality and toxic elements in the food chain (Huq et al., 2006; Altieri, 2009; Chowdhury, 2010; Khan et al., 2011; Munnaf et al., 2015; Hassan, 2015). A summary of the key risks due to 'risk ignorance' or lack of producers' capacity of risks mitigation is given as follows:

(i) Overuse and inappropriate use of agrochemicals, overuse and imbalanced use of irrigation, inorganic fertilizers and pesticides leading to contamination of water, loss of genetic diversity and deterioration of soil quality.
(ii) Increasing evidence of human health problems associated with agricultural production, consumption of agrochemicals (including pesticides) and adding of prohibited or hazardous chemicals to foods and foodstuffs for food adulteration. Post-harvest preservation and processing are also emerging as toxic elements in the food chain.
(iii) Increased risks of implementation of climate change adaptation strategies by ignoring (based on Divine Retribution concept) the linkages of the impacts of climate change to the risks of natural events such as

*Corresponding author. E-mail: mzillur@ruc.dk, zillur45@yahoo.com

drought and floods.

Thus, the above concerns highlight the urgent need to explore the potential strategy to reduce future producers' risky behaviour towards sustainable agricultural food production. In recent years, technological approaches including 'information technology' in a global context have increasingly become an important aspect of environmental sustainability including sustainable rural development (Dao et al., 2011; Unwin, 2009; Schafft et al., 2006; Forsyth, 2014). It is widely accepted that vocational education and training (VET) plays an exceptional role in the development of a skilled work force as a contribution on the road to innovation and economic competitiveness (BANBEIS, 2012; Mahmud et al., 2014; Shan et al., 2015). This can further integrate valuable local knowledge to share with farmers local stories and experiences related to risks perceptions and local mitigation approaches. However, the process is far incomplete, not only in implementation but also in policy analysis (Rivera, 2011). Therefore, the aim of this review is to analyse the existing literature and identify a holistic conceptual framework of agricultural knowledge system (AKS), which can be used to increase agricultural-based producers' adaptive knowledge capacity. It is required because the basic principle of a conceptual framework is the construction or assembly of a broad set of ideas to describe how a system operates with the intention of developing a better understanding of the underlying relationships in the field of enquiry (Korb and Nicholson, 2004; Bredehoeft, 2005; Trkman and Turk, 2009; Kroeger and Weber, 2014, Carayon et al., 2015). The framework provides an explicit structure of thinking within which the reality can be examined (Knol et al., 2010). Smyth (2004) points out that a well-articulated conceptual framework can act as a scaffold on which to build research.

PROPOSED INTEGRATED CONCEPTUAL FRAMEWORK AND RELEVANT LITERATURE

Studies about farmers' *risk perception* have been conducted in many countries (Finucane and Holup, 2005; Adrian et al., 2005; Guehlstorf, 2008; Hashemi and Damalas, 2010; Duinen et al., 2014; Ayinde et al., 2014; Remoundou et al., 2015), and in Bangladesh (Robinson et al., 2007; Hossain et al., 2013). Yet less attention has been given to investigate: what extent addressing producers risk ignorance is important for the effectiveness of agricultural extension policies? How can agri-based vocational education be reinforced with making technological resources more available to change producer's less risky and more sustainable behaviour? Interrelated issues in Bangladesh, such as inadequate institutional support, more centralized, hierarchical and top-down strategies resulted in less impacts of technological approaches for local farmers' capacity development, especially to address climate change induced risks and harmful pesticides use (Balaji et al., 2007; Rahman and Siddiquee, 2015; Parvin et al., 2015).

For a long time (more than four decades), risk research has developed various concepts of risks and identified strategies to manage those environmental risks (Renn, 1998; Vandermoere, 2008). However, two contrasting concepts of risks perceptions are highly relevant, for instant risk as a physical reality existing independently of our knowledge of it (*the realist approach*), and secondly risk as a *social construct*, with emphasis on the contrasting and whether it is useless or at least not sufficient of educating the public with only non- social forms of knowledge or argument (Otway and Thomas, 1982). Similarly, *risk ignorance* is a multidimensional concept with various facets (Raghunathan and Koehler, 2004; Ehrich and Irwin, 2005; Kutsch and Hall, 2010; Poullis et al., 2015), although it is often cited as a lack of 'true' knowledge and people's evaluation behaviour during information retrieval system interactions (Greisdorf, 2003). Ignorance is closely linked to relation between judgments of probability and preferences between bets and sometimes people even pay a significant premium to bet on their judgments (Heath and Tversky, 1991). However, the issue of risk ignorance is influenced by various factors; it is linked with either an 'error' (similar of the realist approach of risk perception), meaning it is beyond one's control, both systemically and cognitively (Slovic et al., 2004; Paharia et al., 2013), or '*deliberate or wilful'* ignorance or irrelevance (similar to *the social constructive approach* of risk perception), driven by social factors and conditioning (Raghunathan and Koehler, 2004; Kutsch and Hall, 2010). Perfect knowledge about an issue is not always possible, and error will occur despite attempts of corrections. However, in contrast, deliberate ignorance is defined as irrelevance (Smithson, 1989; 2010). It is not that information is missing or wrong, but rather that the presence of particular information is not deemed important by stakeholders' risk in a particular contexts (Kelsey and Quiggin, 1992; Ehrich and Irwin, 2005). An integrated conceptual framework is developed (Figure 1) based on relevant literature presented in this paper.

Adaptive innovation

The development and diffusion of IT in appropriate manner are considered to be one of the most relevant options, which can further help local farmers to address risks (UNFCCC, 2006; Below et al., 2010; Lybbert and Sumner, 2010). An 'innovation' of an integrated agricultural knowledge system embedded with Agri-based vocational education and IT resources would enable extension workers and farmers have high levels of interaction, especially about risks (Gandhi et al., 2007). 'Innovation' in this case links to 'social innovation' (Brown and Wyatt, 2010; Phills et al., 2008), which can be well

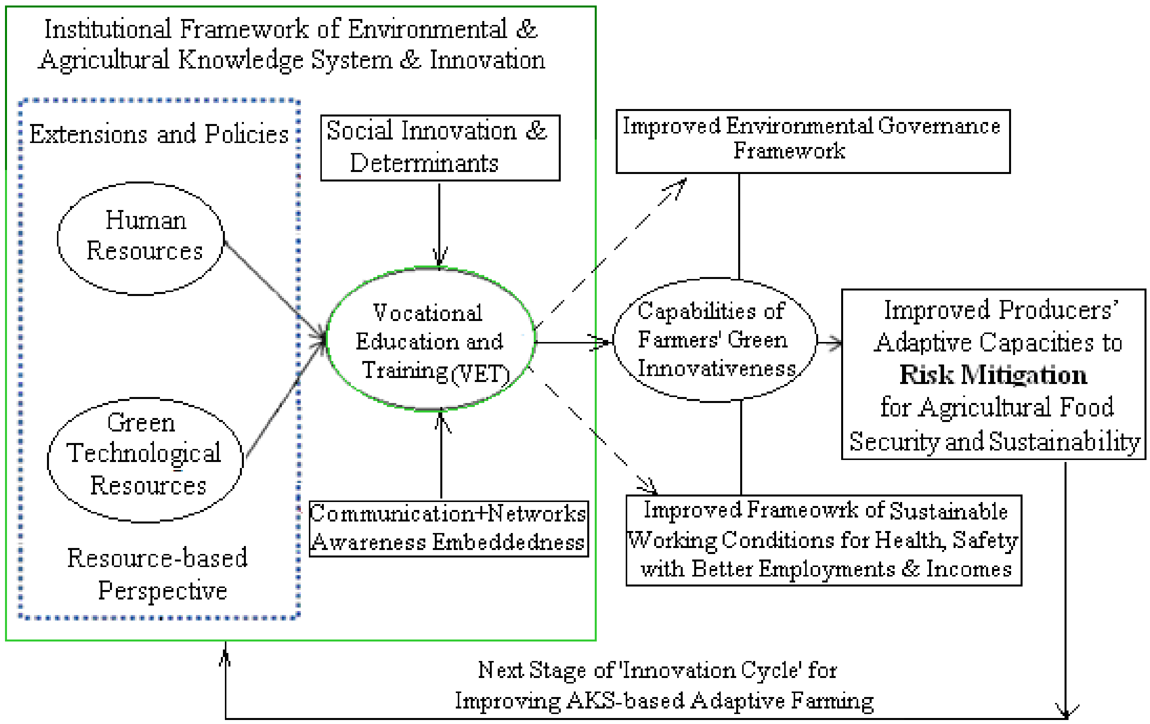

Figure 1. 'Innovation-cycle Framework' of TVET integrated agricultural knowledge system to improve producers' risk perception and mitigation capacities.

placed for an effective planning to develop 'Next Frontier of Innovation' (Brown and Hagel, 2005; Goldblatt, 2010) to fulfil the demand of safe agricultural food supply. It is important that there is a critical need to understand the role of local people, society and their institutions as mechanisms for negotiating socio-ecological and socio-technical change in natural resource management (Niemeyer et al., 2005; Kofinas, 2009; Smith and Stirling, 2010). Ideal selection of local 'entrepreneurship' thus can be a mechanism for empowering innovation.

Moreover, 'innovation' is generally defined as that which introduces something new, makes changes in anything established (Tanimoto, 2010). According to Drucker, 'social innovation' includes not only technology but also frameworks of social insurance and healthcare which have a huge impact on society (Drucker, 1987; Drucker and Drucker, 2007). Social innovation is considered as important element for enhancing sustainable human–environment interactions (Baker and Mehmood, 2015).

The needs of unifying social and technological innovation are discussed by Gardner et al. (2007) in the context of global health issues. Gardner et al. (2007) pointed out that 'innovation' should be understood as the entire process from idea to implementation (Figure 1). Particularly improving access to essential products and services requires three forms of innovations (Gardner et al., 2007), such as '1) '*technological innovation*' to ensure availability of products that are more cost-effective than existing. This innovation involves solutions in technological aspects 2) '*social innovation*' to ensure the distribution of essential goods and services and understanding the adaptive process in complex socio-ecological systems (Baker and Mehmood, 2015); and 3) '*adaptive innovation*' involving both providers and communities, to conceptualize the adaptation of goods and services to local settings.

Both social and adaptive innovations involve solutions those are new ways to recognize human resources, information, and decision making in environment and risks management. There-fore, in all cases, 'innovation' involves both the solutions and its implementations (Gardner et al., 2007), especially 'adaptive innovation' that links both providers and communities.

TVET for green innovativeness and sustainability

The positive impact of using technology, to help solve environmental problems and improve users capacity for sustainability, is referred to as green technology (Watson et al., 2010; Green, 2015). The potential environmental benefits enabled by technology and information technology include prevention of pollution, reducing the environmental footprint of communities, businesses, supply chains and nation and enforce people's behavioural changes (Melville, 2010; Davidson et al., 2011). Studies have shown that technological innovation with information technology is useful to boost agricultural knowledge by enabling rural people to gather, store, retrieve, adapt, localize and disseminate a broad range of information needed (Davison et al., 2005; Balaji et al., 2007; Tambo and Abdoulaye, 2012).

However, issues such as inadequate institutional support, complex characteristics of agricultural extension systems due to continued emphasis on more centralized, hierarchical and top-down approaches have resulted in less impact of technological approaches on local farmers' capacity development; specially to address climate change induced risks, which include risks due to harmful pesticides use (Balaji et al., 2007). In the context of technological innovation, Technical and Vocational Education and Training (TVET) is an important approach to education and job training in modern educational systems in both developed and developing countries (Gazi et al., 2009).

TVET integrated education is very necessary for nation building because of the production of skill manpower through improving resource-based perspective (Green-technology resources and Human resources). These resource-based perspective linked to agriculture could easily be integrated with agricultural extension for better services and productivities. Yet, in relation to local producers capacity building in environmental risks mitigation, significant investments are needed to develop effective agricultural education systems.

According to Benitez-Amado et al. (2010) technological oriented education, capabilities local green innovativeness and capacities of risk mitigation are interlinked. Technological resources at vocational institutes can improve TVET institutes' learning environment for understanding of sustainability and green creativity. That can empower local farmers with adequate technical knowledge related energy efficiency including use of renewable energy resources for agriculture and potential adaptive measures. It will enable farmers to exchange knowledge and collaborate with other producers as shown in Figure 1.

Networks, communication and awareness embeddedness

Collaboration, communication and networks embeddedness are assumed to be important factors of successful agricultural-based TVET and environmental awareness development. Environmental knowledge sharing among community members are highly influenced by the patterns of social networks and knowledge passing from elders (Rahman, 2013). Thus, in order to address the issues of above pointed risk ignorance and mitigation problems and to improve actionable strategies, it is important to collaborate from the beginning with relevant stakeholders in the process (Figure 1). Moreover collaboration, networks and collective participation in sustainable development are important aspects in awareness building (Kofinas, 2009; Walker et al., 2015). It provides better understanding the relationship among institutions, organizations, networks and individuals within and across multiple scales (Chapin III et al., 2009; Taylor and Van Grieken, 2015), which in turn leads to develop a long-term planning (Kemp et al., 2007, 2009).

According to Fowles (2000) The frame-work's collaborative participation can be described as the transformation from the 'ignorance' into a complementary 'knowledge' through participation, collaboration and continuous learning through reinvesting the improved human capital as shown in Figure 1 (feedback line: Innovation cycle).

CONCLUSION

The review presented has shown that increasing ignorance of environmental and health 'risks' by producers is 'in an alarming state' that will pose huge challenges for sustainability of the next growing population in Bangladesh. Although there are initiatives for incremental development initiatives, however, still major change initiatives are missing as described in the review. Therefore, with the growing technological resources, a 'game changer' initiative must be considered together with society as an integrated component. In response, this review has painted and developed an innovation-cycle oriented integrated conceptual framework that highlights the option of 'Next Frontier of Green Innovation'. This is a significant step forward by using local context with state-of-the-art technological availability and vocational training. The initiative is not only a significant step to address the potential climate change adaptation strategy, but also to improve producers' social and technical understanding of risk perception for 'risk mitigation to develop sustainable and green agricultural systems in Bangladesh.

Further development

The above presented 'TVET-adaptive innovation-cycle conceptual framework' is being developed by author as 'first step' of a proposed research project 'Agricultural Knowledge System and Innovation' at Humboldt University in Berlin, Germany. To address the point of 'networks, communication embeddedness', the author has also established an international consortium 'AKSinDC' (Agricultural Knowledge System and Innovation in Developing Countries) and 'KRS Nexus' (KnowledgeSociety-ResourceEfficiency-Sustainability Nexus). In future, empirical research results will be presented based on this framework.

Conflict of Interest

The author has not declared any conflict of interest.

REFERENCES

Adger WN, Pulhin JM, Barnett J, Dabelko GD, Hovelsrud GK, Levy MÚ, Oswald S, Vogel CH (2014). Human Security. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada, YO, Genova RC, Girma B, Kissel ES, Levy AN, Maccracken S, Mastrandrea PR, White LL (eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Adrian AM, Norwood SH, Mask PL (2005). Producers' perceptions and attitudes toward precision agriculture technologies. Comput. Electr. Agric. 48:256-271.

Ahmed A, Masud MM, Al-Amin AQ, Yahaya SRB, Rahman M, Akhtar R (2015). Exploring factors influencing farmers' willingness to pay (WTP) for a planned adaptation programme to address climatic issues in agricultural sectors. Environ. Sci. Poll. Res. pp. 1-11.

Ahmed N, Bunting SW, Rahman S, Garforth CJ (2014). Community-based climate change adaptation strategies for integrated prawn–fish–rice farming in Bangladesh to promote social–ecological resilience. Rev. Aquac. 6:20-35.

Ahmed R (2010). Bangladesh. In: Saravanan, R. (ed.), ICTs for Agricultural Extension: Global Experiments, Innovations and Experiences. New India Publishing.

Ali ANMA (2013). Food safety and public health issues in Bangladesh: a regulatory.

Altieri MA (2009). Agroecology, small farms and food sovereignty. Monthly Rev. 61:102-113.

Amin MR, Zhang J, Yang M (2015). Effects of climate change on the yield and cropping area of major food crops: A case of Bangladesh. Sustainability 7:898-915.

Ayinde O, Muchie M, Olatinwo K, Adenuga A, Oyewole A (2014). Analysis of adoption and risk perception in innovation system in Kwara state Nigeria: a case study of improved rice. Int. J. Agric. Sci. 10:816-822.

Baker S, Mehmood A (2015). Social innovation and the governance of sustainable places. Local Environ. 20:321-334.

Balaji V, Meera SN, Dixit S (2007). ICT-enabled knowledge sharing in support of extension: addressing the agrarian challenges of the developing world threatened by climate change, with a case study from India. SAT ejournal 4:18.

BANBEIS (2012). School Education. In: BANBEIS, BBOEIS.(ed.). Dhaka: Bangladesh Bureau of Educational Information & Statistics (BANBEIS).

Banerjee RR (2015). Farmers' perception of climate change, impact and adaptation strategies: a case study of four villages in the semi-arid regions of India. Nat.Hazards. 75:2829-2845.

Barros V, Field C, Dokke D, Mastrandrea M, Mach K, Bilir T, Chatterjee M, Ebi K, Estrada Y, Genova R (2015). Climate change 2014: impacts, adaptation, and vulnerability. Part B: Regional aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Below T, Artner A, Siebert R, Sieber S (2010). Micro-level practices to adapt to climate change for African small-scale farmers. A Review of Selected Literature. Environment and Production Technology Division. International Food Policy Research Institute (IFPRI).

Benitez-Amado J, Nieves Perez-Arostegui M, Tamayo-Torres J (2010). Information technology-enabled innovativeness and green capabilities. J. Comput. Inform. Syst. 51:87-96.

Berkhout E, Glover D, Kuyvenhoven A (2015). On-farm impact of the System of Rice Intensification (SRI): Evidence and knowledge gaps. Agric. Syst. 132:157-166.

Biswas WK, Bryce P, Diesendorf M (2001). Model for empowering rural poor through renewable energy technologies in Bangladesh. Environ. Sci. Policy 4:333-344.

Bredehoeft J (2005). The conceptualization model problem-surprise. Hydrogeol. J. 13:37-46.

Brown JS, Hagel J (2005). The next frontier of innovation. McKinsey Q. 3:83-91.

Brown T, Wyatt J (2010). Design thinking for social innovation. Stanford Social Innovation Review. pp. 1-35.

Carayon P, Hancock P, Leveson N, Noy I, Sznelwar L, Van Hootegem G (2015). Advancing a sociotechnical systems approach to workplace safety–developing the conceptual framework. Ergonomics 58(4):548-64.

Chapin III FS, Folke C, Kofinas GP (2009). A framework for understanding change. In: F.S. Chapin III, G.P. Kofinas, and C. Folke (eds.), Principles of Ecosystem Stewardship: Resilience-Based Natural Resource Management in a Changing World. Springer Verlag, New York. pp. 3-28.

Chen S, Chen X, Xu J (2015). Impacts of climate change on agriculture: Evidence from China. J. Environ. Econ. Manag. (In Press)

Chen Y, Ahsan H, Parvez F, Howe GR (2004). Validity of a food-frequency questionnaire for a large prospective cohort study in Bangladesh. British J. Nutr. 92:851-859.

Chowdhury N (2010). Water management in Bangladesh: an analytical review. Water Policy, 12:32-51.

Dao V, Langella I, Carbo, J (2011). From green to sustainability: Information Technology and an integrated sustainability framework. J. Strateg. Inform. Syst. 20:63-79.

Dasgupta S, Meisner C, Huq M (2005). Health effects and pesticide perception as determinants of pesticide use: evidence from Bangladesh. World Bank, Washington, DC. https://openknowledge.worldbank.org/bitstream/handle/10986/8572/wps3776.pdf?sequence=1

Davidson E, Vaast E, Wang P (2011). The greening of IT: How discourse informs IT sustainability innovation. In: Commerce and Enterprise Computing (CEC), 2011 IEEE 13th Conference. IEEE, pp. 421-427.

Davison RM, Harris RW, Qureshi S, Vogel DR, De Vreede GJ (2005). Information systems in developing countries: theory and practice. City University of HK Press.

Domínguez IP, Fellmann T (2015). The Need for Comprehensive Climate Change Mitigation Policies in European Agriculture. EuroChoices 14:11-16.

Drucker PF (1987). Innovation and entrepreneurship. Newbridge Communications.

Drucker PF (2007). Innovation and entrepreneurship: Practice and principles. Routledge.

Duinen RV, Filatova T, Geurts P, Veen AVD (2014). Empirical Analysis of Farmers' Drought Risk Perception: Objective Factors, Personal Circumstances, and Social Influence. Risk Anal. doi: 10.1111/risa.12299

Ehrich KR, Irwin JR (2005). Wilful ignorance in the request for product attribute information. J. Market. Res. 42:266-277.

Finucane ML, Holup JL (2005). Psychosocial and cultural factors affecting the perceived risk of genetically modified food: An overview of the literature. Soc. Sci. Med. 60:1603-1612.

Forsyth T (2014). International investment and climate change: Energy technologies for developing countries. Routledge.

Fowles RA (2000). Symmetry in design participation in the built environment: Experiences and insights from education and practice. In: Proceedings of Co-Designing. London: Springer.

Gandhi R, Veeraraghavan R, Toyama K, Ramprasad V (2007). Digital green: Participatory video for agricultural extension. Information and Communication Technologies and Development, ICTD 2007. IEEE. pp. 1-10.

Gardner CA, Acharya T, Yach D (2007). Technological And Social Innovation: A Unifying New Paradigm For Global Health. Health Affairs, 26:1052-61.

Gazi MA, Kazi EH, Md TBK, Saedah BS, Muhammad FBAG (2009). The role of agriculture education and training on agriculture economics and national development of Bangladesh. Afr. J. Agric. Res. 4:1334-1350.

Gelfand I, Robertson GP (2015). Mitigation of greenhouse gases in agricultural ecosystems. In: Hamilton SK, Doll JE, Robertson GP (eds.), The Ecology of Agricultural Landscapes: Long-Term Research on the Path to Sustainability. Oxford University Press, New York. pp. 310-339.

Gerlitz JY, Banerjee S, Brooks N, Hunzai K, Macchi M (2014). An Approach to Measure Vulnerability and Adaptation to Climate Change in the Hindu Kush Himalayas. Handbook of Climate Change Adaptation. Springer Berlin Heidelberg. pp. 1-22.

Goldblatt J (2010). Special events: A new generation and the next frontier. John Wiley & Sons. 13.

Greisdorf H (2003). Relevance thresholds: a multi-stage predictive model of how users evaluate information. Inform. Proc. Manage. 39:403-423.

Guehlstorf NP (2008). Understanding the scope of farmer perceptions of risk: considering farmer opinions on the use of genetically modified (GM) crops as a stakeholder voice in policy. J. Agric. Environ. Ethics 21:541-558.

Habiba U, Shaw R, Takeuchi Y 2011. Drought risk reduction through a socio-economic, institutional and physical approach in the Northwestern region of Bangladesh. Environ. Hazards 10:121-138.

Hashemi SM, Damalas CA (2010). Farmers' perceptions of pesticide efficacy: reflections on the importance of pest management practices adoption. J. Sustainab. Agric. 35:69-85.

Hassan MK (2015). Quality management and safety assurance in Horticultural chains of Bangladesh. Res. Agric. Livestock Fishery 1:1-11.

Havlík P, Valin H, Herrero M, Obersteiner M, Schmid E, Rufino MC, Mosnier A, Thornton PK, Böttcher H, Conant RT (2014). Climate change mitigation through livestock system transitions. Proc. Natl. Acad. Sci. 111:3709-3714.

Heath C, Tversky A (1991). Preference and belief: Ambiguity and competence in choice under uncertainty. J. Risk Uncertain. 4:5-28.

Hellberg RS, Chu E (2015). Effects of climate change on the persistence and dispersal of foodborne bacterial pathogens in the outdoor environment: A review. Crit. Rev. Microbiol. pp. 1-25.

Heong KL, Wong L, Reyes JHD (2015). Addressing plant hopper threats to Asian rice farming and food security: Fixing insecticide misuse. ADB Sustainable Development Working Paper Series. pp. 1-12. http://www.adb.org/sites/default/files/publication/30362/adb-wp-27-addressing-planthopper-threats-asian-rice.pdf

Hijioka Y, Lin E, Pereira JJ, Corlett RT, Cui X, Insarov GE, Lasco RD, Lindgren E, Surjan A (2014). Asia. In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, Maccracken S, Mastrandrea PR, White LL. (eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Inter-governmental Panel of Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Hossain MM, Heinonen V, Islam KMZ (2008). Consumption of foods and foodstuffs processed with hazardous chemicals: a case study of Bangladesh. Int. J. Consumer Stud. 32:588-595.

Hossain MS, Hossain MA, Rahman MA, Islam MM, Rahman MA, Adyel TM (2013). Health risk assessment of pesticide residues via dietary intake of market vegetables from Dhaka, Bangladesh. Foods 2:64-75.

Huq SI, Joardar J, Parvin S, Correll R, Naidu R (2006). Arsenic contamination in food-chain: transfer of arsenic into food materials through groundwater irrigation. J. Health Popul. Nutr. 24:305.

IPCC (2014). Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: In: Barros VR, Field CB, Dokken DJ, Mastrandrea MD, Mach KJ, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, MacCracken S, Mastrandrea PR, White LL (eds.), Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, United Kingdom and New York, NY, USA. Cambridge University Press.

Isin S, Yildirim I (2007). Fruit-growers' perceptions on the harmful effects of pesticides and their reflection on practices: The case of Kemalpasa, Turkey. Crop Protect. 26:917-922.

Islam AHMS, Barman BK, Murshed-E-Jahan K (2015). Adoption and Impact of Integrated Rice-Fish Farming System in Bangladesh. Aquaculture Available online 19 January 2015.

Islam MS, Grönlund Å (2007). Agriculture market information e-service in Bangladesh: A stakeholder-oriented case analysis. Electronic Government. Springer.

Jordan JC (2014). Swimming alone? The role of social capital in enhancing local resilience to climate stress: A case study from Bangladesh. Clim. Dev. pp. 1-14.

Kalafatis SE, Lemos MC, Lo YJ, Frank KA (2015). Increasing information usability for climate adaptation: The role of knowledge networks and communities of practice. Glob. Environ. Change 32:30-39.

Kamruzzaman A, Jahan MS, Rahman MR, Khatun MM (2015). Impact of climate change on the outbreak of infectious diseases among children in Bangladesh. Am. J. Health Res. 3:1-7.

Kelsey D, Quiggin J (1992). Theories of choice under ignorance and uncertainty. J. Econ. Sur. 6:133-153.

Kemp R, Loorbach D, Rotmans J (2007). Transition management as a model for managing processes of co-evolution towards sustainable development. Int. J. Sustain. Dev. World Ecol. 14:78-91.

Khan AE, Ireson A, Kovats S, Mojumder SK, Khusru A, Rahman A Vineis P, Labrese EJV (2011). Drinking water salinity and maternal health in coastal Bangladesh: implications of climate change. Environ. Health Perspect. 119:1328-1332.

Knol A, Slottje P, Van Der Sluijs J, Lebret E (2010). The use of expert elicitation in environmental health impact assessment: a seven step procedure. Environ. Health 9:19.

KOFINAS GP (2009). Adaptive co-management in social-ecological governance. Principles of ecosystem stewardship. Springer.

Korb KB, Nicholson AE (2004). Bayesian Artificial Intelligence, Washington, D.C, Chapman & Hall/CRC.

Kroeger A, Weber C (2014). Developing a conceptual framework for comparing social value creation. Acad. Manag. Rev. 2012.0344.

Kutsch E, Hall M (2010). Deliberate ignorance in project risk management. Int. J. Project Manage. 28:245-255.

Lybbert T, Sumner D (2010). Agricultural Technologies for Climate Change Mitigation and Adaptation in Developing Countries: Policy Options for Innovation and Technology Diffusion. ICTSD–IPC Platform on Climate Change, Agriculture and Trade. International Centre for Trade and Sustainable Development, Geneva, Switzerland and International Food & Agricultural Trade Policy Council, Washington DC, USA. Issue Brief No. 6.

Mahmud KT, Parvez A, Hilton D, Kabir G, Wahid IS (2014). The role of training in reducing poverty: the case of agricultural workers receiving microcredit in Bangladesh. Int. J. Train. Dev. 18:282-290.

Makkonen M, Huttunen S, Primmer E, Repo A, Hildén M (2015). Policy coherence in climate change mitigation: An ecosystem service approach to forests as carbon sinks and bioenergy sources. For. Policy Econ. 50:153-162.

Meijer SS, Catacutan D, Ajayi, OC, Sileshi GW, Nieuwenhuis M (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. Int. J. Agric. Sustainb. 13:40-54.

Melville NP (2010). Information systems innovation for environmental sustainability. MIS Q. 34:1-21.

Mishra AK, Mottaleb KA, Khanal, AR, Mohanty S (2015). Abiotic stress and its impact on production efficiency: The case of rice farming in Bangladesh. Agric. Ecosyst. Environ. 199:146-153.

Munnaf A, Islam M, Tusher T, Kabir M, Molla M (2015). Investigation of Water Quality Parameters Discharged from Textile Dyeing Industries. J. Environ. Sci. Nat. Resour. 7:257-263.

Nam WH, Hong EM, Choi JY (2015). Has climate change already affected the spatial distribution and temporal trends of reference evapotranspiration in South Korea. Agric. Water Manage. 150:129-138.

Ngugi L, Rao K, Oyoo A, Kwena K (2015). Opportunities for Coping with Climate Change and Variability Through Adoption of Soil and Water Conservation Technologies in Semi-arid Eastern Kenya. Adapting African Agriculture to Climate Change. Springer. pp. 1-71.

Niemeyer S, Petts J, Hobson K (2005). Rapid climate change and society: Assessing responses and thresholds. Risk Anal. 25:1443-1456.

Niles MT, Lubell M, Brown M (2015). How limiting factors drive agricultural adaptation to climate change. Agric. Ecosyst. Environ. 200:178-185.

Noble IR, Huq S, Anokhin YA, Carmin J, Goudou D, Lansigan FP, Osman-Elasha B, Villamizar A (2014). Adaptation needs and options. In: Field CB, Barros VR, Dokken DJ, Mach KJ, Mastrandrea MD, Bilir TE, Chatterjee M, Ebi KL, Estrada YO, Genova RC, Girma B, Kissel ES, Levy AN, Maccracken S, Mastrandrea PR, White LL (eds.), Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

Otway H, Thomas K (1982). Reflections on Risk Perception and Policy 1, 2. Risk Anal. 2:69-82.

Paul SK, Routray JK (2011). Household response to cycle and induced surge in coastal Bangladesh: coping strategies and explanatory variables. Nat. Hazards 54(2):289-304.

Paharia N, Vohs KD, Deshpandé R (2013). Sweatshop labor is wrong unless the shoes are cute: Cognition can both help and hurt moral motivated reasoning. Organ. Behav. Hum. Dec. Proc. 121:81-88.

Parvez F, Chen Y, Argos M, Hussain AI, Momotaj H, Dhar R, Van Geen A, Graziano JH, Ahsan H (2006). Prevalence of arsenic exposure from drinking water and awareness of its health risks in a Bangladeshi population: results from a large population-based study. Environ. Health Perspect. pp. 355-359.

Parvin GA, Fujita K, Matsuyama A, Shaw R, Sakamoto M (2015). Climate Change, Flood, Food Security and Human Health: Cross-Cutting Issues in Bangladesh. Food Security and Risk Reduction in Bangladesh. Springer.

Phills JA, Deiglmeier K, Miller DT (2008). Rediscovering social innovation. Stanford Soc. Innovat. Rev. 6:34-43.

Poullis C, Mackay A, Ahmed M (2015). When ignorance is not bliss–a study of poor awareness of radiation exposure. J. Clin. Urol. 2051415813518918.

Pretty J (2008). Agricultural sustainability: concepts, principles and evidence. Philos. Trans. Royal Soc. B: Biol. Sci. 363:447-465.

Raghunathan R, Koehler JJ (2004). Willful ignorance: the avoidance of ethical attribute information. Presented to the Faculty of the Graduate School of The University of Texas at Austin in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy. The University of Texas at Austin. pp. 1-88.

Rahman MZ (2013). 'Understanding People's Social Perceptions of Climate Change Impacts on Rural Water Resources in Bangladesh: An Integrated Modelling Approach' Published PhD Thesis- xvi, 239 leaves, The Australian National University (ANU), Canberra, Australia

Rahman MZ, Siddiquee SA (2015). Climate Change and Farming Vulnerability in the Coast of Bangladesh. J. Nat. Sci. Res. 5:202-210.

Rahman S (2003). Farm-level pesticide use in Bangladesh: determinants and awareness. Agric. Ecosyst. Environ. 95:241-252.

Rahman S (2014). Food adulteration poses 'too serious a threat' to public health. The Independent, February 24, 2014.

Rashid S, Tefera N, Lemma S, Yunus M (2014). Population pressure and livelihood dynamics: Panel evidence from Bangladesh. IFPRI Discussion Paper, No. 1326.

Rasul G, Thapa GB (2004). Sustainability of ecological and conventional agricultural systems in Bangladesh: an assessment based on environmental, economic and social perspectives. Agric. Syst. 79:327-351.

Remoundou K, Brennan M, Sacchettini G, Panzone L, Butler-Ellis M, Capri E, Charistou A, Chaideftou E, Gerritsen-Ebben M, Machera K (2015). Perceptions of pesticides exposure risks by operators, workers, residents and bystanders in Greece, Italy and the UK. Sci. Total Environ. 505:1082-1092.

Renn O (1998). Three decades of risk research: Accomplishments and new challenges. J. Risk Res. 1:49-71.

Rivera WM (2011). Public sector agricultural extension system reform and the challenges ahead. J. Agric. Educ. Ext. 17:165-180.

Robinson EJ, Das SR, Chancellor TB (2007). Motivations behind farmers' pesticide use in Bangladesh rice farming. Agric. Hum. Values 24:323-332.

Robson M (2014). Food safety in Bangladesh. The Daily Star, May 8, 2014.

Schafft KA, Alter TR, Bridger JC (2006). Bringing the community along: A case study of a school district's information technology rural development initiative. J. Res. Rural Educ. 21:21-28.

Shan H, Liu Z, Li L (2015). Vocational training for Liushou women in rural China: development by design. J. Vocat. Educ. Train. 67:11-25.

Slovic P, Finucane ML, Peters E, Macgregor DG (2004). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. Risk Anal. 24:311-322.

Smith A, Stirling A (2010). The politics of social-ecological resilience and sustainable socio-technical transitions. Ecol. Soc. 15:11.

Smithson M (1989). Ignorance and uncertainty: Emerging paradigms. Springer-Verlag Publishing.

Smithson M (2010). Ignorance and uncertainty. Tackling wicked problems through the transdisciplinary imagination. pp. 84-97.

Smyth R (2004). Exploring the usefulness of a conceptual framework as a research tool: A researcher's reflections. Iss. Educ. Res. 14:167-180.

Tambo JA, Abdoulaye T (2012). Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. Mitigation Adapt. Strateg. Glob. Change 17:277-292.

Tanimoto K (2010). The process of social innovation: Multi-stakeholders perspective. 2010/09/Sep (2010) Reading. Academic Conferences International Limited. pp. 594-598.

Taylor B, Van Grieken M (2015). Local institutions and farmer participation in agri-environmental schemes. J. Rural Stud. 37:10-19.

Trkman P, Turk T (2009). A conceptual model for the development of broadband and e-government. Gov. Information Q. 26:416-424.

Truelove HB, Carrico AR, Thabrew L (2015). A socio-psychological model for analyzing climate change adaptation: A case study of Sri Lankan paddy farmers. Glob. Environ. Change 31:85-97.

Uddin ME, Qijie G (2013). Prospects and challenges of privatization of agricultural extension service in Bangladesh. Asian J. Agric. Rural Dev. 3:477-487.

Unwin P (2009). ICT4D: Information and communication technology for development, Cambridge University Press.

Vandermoere F (2008). Hazard perception, risk perception, and the need for decontamination by residents exposed to soil pollution: the role of sustainability and the limits of expert knowledge. Risk Anal. 28:387-398.

Walker AH, Pavia R, Bostrom A, Leschine TM, Starbird K (2015). Communication practices for oil spills: Stakeholder engagement during preparedness and response. Hum. Ecol. Risk Assess. 21:667-690.

Waongo M, Laux P, Kunstmann H (2015). Adaptation to climate change: The impacts of optimized planting dates on attainable maize yields under rainfed conditions in Burkina Faso. Agric. For. Meteorol. 205:23-39.

Watson RT, Boudreau MC, Chen AJ (2010). Information systems and environmentally sustainable development: energy informatics and new directions for the IS community. Manag. Information Syst. Q. 34:4.

Wood SA, Mendelsohn RO (2015). The impact of climate change on agricultural net revenue: a case study in the Fouta Djallon, West Africa. Environ. Develop. Econ. 20:20-36.

Wooster GA, Martinez CM, Bowser PR, O'hara DS (2005). Human health risks associated with formalin treatments used in aquaculture: initial study. North Am. J. Aquac. 67:111-113.