Using ICT for Climate Change Adaptation and Mitigation through Agro-ecology in the Developing World

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ABSTRACT

This paper explores three interconnected issues of relevance to sustainability and climate change: agro-ecological farming, poverty reduction and information and communication technologies (ICT) in developing countries. It collates evidence from different sources pointing to the potential benefits of agro-ecological farming methods for climate change adaptation and its poverty-reduction possibilities. Despite the importance of on-farm production of organic inputs for farmers practicing climate compatible agriculture, this is unlikely to be sufficient for scaling to a level required for mitigation and adaptation in a timely manner. However, the scaling up of production could speed the expansion of such methods and at the same time create employment opportunities in rural non-farm sectors. This paper points to the important role ICTs can play in this process, and is a working hypothesis calling for action by policy-makers, researchers, donors, and entrepreneurs, including social enterprises, to grasp this opportunity, whether to conduct further research, policy dialogues or pilot implementations.

Keywords

Agro-ecological farming, climate change, information and communication technologies (ICT), sustainable development

1. INTRODUCTION

The body of work revolving around ICT and environmental issues has long recognised the potential of ICT to contribute to sustainability [1],[2], and has more recently engaged in addressing environmental challenges associated with its production, use and disposal. Some aspects of its positive potential were enshrined in what Hilty & Ruddy [3] referred to as the 'techno-optimistic' view in the WSIS Geneva Plan of Action, which encouraged the use of ICTs for environmental protection, sustainable production and disaster forecasting and monitoring systems [4]. Referring to the Millennium Development Goal number 7, "ensure environmental sustainability", UNICT [5] pointed to similar contributions as well as facilitating environmental activism and enabling more efficient resource use. The outcome document of Rio+20 [6], acknowledged the importance of ICT in the context of sustainable development for facilitating the flow of information between governments and the public (paragraph 44), for sharing knowledge and good practices related to agriculture (paragraph 11), and for enhancing learning outcomes that prepare people to pursue sustainable development (paragraph 230).

Much attention has been paid to the potential of ICT in reducing greenhouse gas (GHG) emissions, increasing energy efficiency and security by investing in sustainability, as well as its contribution to e-waste and an increase in GHG emissions associated with ICT's energy use [7]. But ICT's energy use is still well below that of agriculture, which contributes between a quarter and a third of the GHG emissions that cause global climate change – it is directly responsible for 13% (including from fertilisers and livestock), and indirectly it is largely responsible for another 17%, mainly through deforestation and land use changes [8],[9]. Agriculture is, like ICT, both part of the problem and the solution to climate change. Like ICT, there is potential to reduce, but not eliminate, GHGs from agriculture.

Dependent on agriculture, while experiencing weak infrastructures and high population growth, countries in the developing world are particularly vulnerable to the socio-economic impacts of climate change [9]. It is now widely recognised that ICT infrastructure in rural communities can stimulate growth in sustainable agriculture, providing employment and other development opportunities [10] and while there is considerable anecdotal evidence from various pilots, there does not seem to be much widescale realisation of this potential. There is no clear definition of sustainable agriculture and different terminologies are used for various methods and practices that fit broadly within this definition - e.g. conservation agriculture [11], agro-ecological practices [12], agri-environmental [13] or ecological agriculture, climate-smart agriculture and organic farming. Each of these encompasses a wide range of practices, from replacement of at least some agrochemicals with organic inputs to certified organic produce. Lacking specific definitions, these terms are often used interchangeably, contrasting them with what is generally referred to as "conventional" agriculture. There would be advantages in an agreed taxonomy in this field, but the lack of it does not detract from the objectives of this paper, which presents a working hypothesis related to ICT use for more sustainable agriculture.

Although it might be desirable to focus on the use of ICTs more holistically in agriculture and climate change, when it comes to suggesting actionable policies, it is often easier to focus on one specific issue, rather than approach the challenge from a more general perspective and call for paradigm shifts. Hence, by way of illustration of how ICT could be used to encourage ecological agriculture, this paper concerns itself with the particular issue of scaling up agricultural inputs for organic farming. In doing so, we have placed emphasis on a call to action.

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Building an argument for the benefits of agro-ecological farming for climate change adaptation, mitigation and poverty reduction, this paper suggests that in order to realise the potential of organic agriculture, it will be necessary to scale the dispersed implementations of this form of farming. There are different ways in which scaling can take place - e.g. NGOs who are already involved in raising awareness and imparting skills in agro-ecology could become catalysts for policy innovations that are then integrated into government and market institutions, similar to the way NGO projects in general can be scaled [14]. Scaling of agro-ecological farming to a level where practice would have noticeable adaptation and mitigation impacts is, however, likely to require the up-scaling of organic input [10]. It is argued herein that government intervention would be required to instigate this, in order to exploit it in ways that would also contribute to poverty reduction. ICT would play an important role in the establishment and operations of this new sub-sector. Other areas where ICTs can be involved in the process towards greener agriculture include training farmers in the use of agro-ecological techniques and in marketing – buying and selling agricultural inputs and produce. These are covered in subsequent sections, followed by a discussion of the types of ICTs that are suitable for this process. The paper then considers the factors required in an enabling environment for promoting a quantitative leap in the application of sustainable organic farming methods, with attention to realising their poverty reduction potential.

2. AGRO-ECOLOGICAL FARMING AS A CLIMATE ADAPTATION/MITIGATION AND POVERTY REDUCTION STRATEGY

Industrial agriculture accounts for proportionately higher adverse environmental impacts than does lower-yield traditional farming [10] but these environmental costs of production are often externalised, paid for by those most exposed to these impacts, often the poorest people in developing countries. There is, then, a danger of a vicious cycle through which poverty fuelled by environmental degradation encourages farmers to clear land, which in turn further degrades the environment.

In addressing the challenge of how to exit this cycle by improving the efficiency of traditional farming without increasing adverse impacts, the climate change adaptation and mitigation potential of organic agriculture has sparked renewed interest. Without overstating the significance of this move, its extension from the niche to the mainstream literature is a clear indication. The debate has been underpinned by scientific and theoretical inquiry related to agro-ecological methods in support of global movements adopting such techniques [15]. This includes those wishing to at least reduce the amount of chemical inputs, rather than going all the way to having their produce certified as organic. There are several processes through which these practices contribute to sustainability and climate change adaptation and mitigation.

The use of organic matter for composting instead of burning reduces pollution and has health benefits as well as improving soil fertility as plant residue is "ploughed back" into the fields [16], [17]. The water holding capacity of soils is increased from recycling crop residues, animal manure and other techniques used in organic farming, thereby improving water absorption capacity during rains and mitigating flooding [10]. As inorganic fertilisers are a major source of methane gas emissions and contamination of land and water [18],[19], the reduction in use of chemical inputs lowers the risks of water and aquatic food pollution affecting organisms not intentionally targeted. There can be specific health problems with chemical pesticides arising from inappropriate use, with farmers often ignoring or misunderstanding labels - e.g. in Cambodia labels on illegally imported sprays have been written in Vietnamese or Thai [20]. In South Africa, women have been found to lack knowledge about the pesticides with which they come into contact [21]. Combined with other sustainability measures (e.g. replacing dung with clean cooking facilities and instead using it for producing organic input), a transition to agro-ecological practices can have multiple positive environmental impacts – pollution reduction, better working conditions and associated health improvements and the production of organic input. There can also be socio-economic benefits: farmers using organic inputs tend to be less indebted than farmers using chemical inputs [10]. These potential poverty-reducing characteristics particularly benefit women because of the difficulties they often encounter in accessing external farm inputs [12].

Organic farming is by no means the only type of sustainable agriculture. Other methods, which could also incorporate organic practices include diversified crop rotations, improved nutrient and water use efficiency, using crops resistant to pests and disease, agroforestry and minimum tillage to reduce soil erosion and increase the soil's capacity to hold water and sequester CO2 [8].

The greater interest in agro-ecological methods is manifested in an increase in the arable land dedicated to organic crops – from a negligible level in 1990 to some 2% in 2010 [10]. A study of the relationship between organic agriculture and food security in East Africa, found that the yields of small-scale farmers surveyed for the study had on average doubled after conversion to organic or near organic methods [22]. The methods also resulted in healthier and more stable soils that are better able to hold water, and sustain plant growth through higher nutrient content. The study concluded that the findings would be relevant for the rest of Africa as well as many other developing countries. This claim might be exaggerated, as the benefits of organic agriculture are contested and multiple perspectives on this issue are acknowledged.

A meta-analysis covering 62 study sites, 316 yield comparisons and 34 different crop species [23] found that overall, organic yields were typically lower than conventional yields. The researchers cautioned this could encourage farmers using organic methods to clear more land for cultivation, thereby contributing to deforestation, as only limited new land is available for agriculture. The different views could relate to the contextual nature of agriculture, both in terms of space and time, as it can take several years for organic agriculture to reach comparable yields to optimal application of chemical inputs. For example, an evaluation of Korea's Environmentally Friendly Direct Payment Programme showed that it was not until the fifth year after the change that the gross margin of organic farming exceeded that of conventional farming [24]. So the question is how farmers can be encouraged to make the transition. Policy measures, such as subsidies to farmers during the period of conversion to more climate compatible methods, would be necessary to ease the transition and to avoid the compromise of food security. More importantly, property rights must be addressed in order for farmers to have the incentive to invest in long term improvement of their land-holdings. In the longer term, if more resources are allocated to

research into agro-ecological approaches, it may be possible that the time to reach the break-even can be reduced.

Notwithstanding the studies questioning certain aspects of agro-ecological farming, we proceed on the assumption that its advantages can exceed its disadvantages, at least for crops that can can generate yields that are not below those of conventional farming within a reasonable timescale and with adequate support during the transition phase. Much research evidence is already available to inform policy on these issues. In addition to using their local knowledge, which is often of an agro-ecological nature, farmers in many developing countries can take advantage of formal research in this area. With the likely increase in the cost of inorganic inputs in combination with greater awareness of the health benefits of organic farming, the growth in organic farming may accelerate, but it may be necessary to give it some additional impetus.

Currently, organic agriculture in developing countries is largely based on farmers creating their own organic matter, particularly fertilisers. Despite the importance of on-farm production of organic inputs, this is unlikely to be sufficient for scaling organic farming to a level required for mitigation and adaptation in a timely manner. One option for scaling, suggested in this paper is to place greater emphasis on off-farm production of such inputs on a commercial or community basis. If implemented with community participation, subject to addressing the intricacies of power relations at this level, it could at the same time become an instrument for poverty reduction and food security. This could be an opportunity to integrate climate and human development objectives, including agency and empowerment, into a new sub-sector, but the danger that such an initiative be captured by existing power structures must be avoided for this objective to be achieved. ICT, with its ability to facilitate transparency could be a useful tool in this process, but not the driver.

The availability of physical inputs and an adequate institutional framework are not sufficient to change farm practices. Knowledge, the essential component of human capital, is paramount. It is at the core of the adoption of any innovation, not only about a specific method, but also knowledge that the innovation has no disadvantage and preferably a certain advantage over already known methods. Knowledge is particularly important for agro-ecology [10],[12], which may require greater understanding of ecology than farming based on chemical inputs. ICT has an important role to play in the formation of required knowledge in this field. A further role for ICT in this process relates to marketing.

3. USING ICTs FOR SCALING ORGANIC INPUTS

Several international agencies have engaged with the issue of intensification and/or extension of sustainable agriculture and one of the opportunities identified by the United National Environment Programme [10] to achieve this was scaling up production of green agricultural inputs. This paper takes as a starting point that it might be desirable to expand the use organic inputs by manufacturing at least some of these in the developing world, embedding the activities in local communities.

While there is a large commercial market for organically certified agricultural inputs in the developed world, referred to as input substitution, including manufactured products to control weeds, pests and diseases, as well as maintaining soil fertility [25], this is generally not the case in developing countries. Products for soil and plant nutrition probably hold the greatest promise for initial scaling at a community level, as the inputs are readily available, particularly where livestock is an integral part of mixed farming systems. The production of organic fertilisers also has considerable scope for employment creation.

One example of this is the Waste Concern, generating compost from organic waste in Dhaka, Bangladesh, which helped create 400 new jobs in collection activities and 800 new jobs in the process of composting. The daily collection of 700 tonnes of organic waste yielded 50,000 tonnes of compost per year [26]. The fact that this operation is based in Dhaka indicates that this sub-sector can create employment in urban as well as rural areas and that the benefits can be two-fold: a way of managing organic waste in a large metropolitan area and producing organic inputs to agriculture. As the compost is sold to existing fertiliser companies, which then enrich it, the end product may not be fully organic, but nevertheless reduces the reliance of chemical ingredients. However, despite Waste Concern having been in operation since 1995, according to Rashid [27], the compost sector in Bangladesh faces constraints in three areas: licensing procedures, weak market demand for composting and lack of awareness among farmers of the benefits of using compost.

This suggests that some form of state intervention may be necessary, at a minimum in creating an enabling environment and stimulating demand by raising awareness. It may even be necessary to go as far as involving the state in a more active way in the establishment of this sector - e.g. in partnership, possibly with producer organisations, which are now emerging in developing countries to represent the interest of poor smallholders [8]. The latter can then facilitate engagement of community energies in asset-building activities in an endeavour that has both economic and environmental benefits, while at the same time minimising the risk of capture and exploitation by intermediaries.

Because of the knowledge-intensity of sustainable agriculture systems, consideration must be given to information and knowledge, throughout the development phase of the proposed initiative, thereby paying attention to the ICT infrastructure, which has to be integral rather than bolted on.

Information in this context refers to facts, whereas knowledge incorporates what is known. As information is not automatically converted into knowledge, the information systems must be designed around the various stakeholders and their requirements - e.g. farmers both as users and possibly suppliers of inputs as well as suppliers of output. Farmers also need information for educational purposes - e.g. through open distance learning (ODL), that will enable them to understand benefits and learn about new practices. ODL is now used extensively for tertiary education in the developing world, and has also been used to help farmers improve agricultural production. The latter is a greater challenge due to low literacy rates. Employees or sub-contractors engaged in collecting would require education to learn about the quality of the input and be able to communicate effectively with farmers and producers to arrange for pick-up and delivery. Although a participatory design process involving the various stakeholder categories is likely to be more complex and time-consuming, it would probably help ensure the usability and "ownership" of a system incorporating the above requirements, as well as information for managing the production, marketing and distribution systems.

It is envisaged that, at the core of the system in a country, there would be a portal or other electronic venue for managing this process, including details on demand, pricing and collection arrangements for organic input. The portal could also bring together farmers, extension workers and researchers for knowledge exchange. It would be designed for use by farmers who want to purchase organic input and those who want to sell ingredients to the production processes, as well as anyone else in the supply/demand chain. Other players in this chain would be able and encouraged to establish their own Internet presence, but it is important that there is one authoritative information source all actors can trust. In order for trust to be sustained, a high level of quality control would have to be established in all aspects of the operation, from the accuracy of information disseminated via this system to the production and distribution processes, as well as its governance. While information and communication would be integral to the many functions of this system, ICT cannot drive it. This must be done by an appropriate institutional framework.

There are examples of agriculture portals targeting actors in the agriculture supply chain in developing countries (e.g. b2bpricenow.com, an e-commerce platform in the Philippines). The proposed platform would go beyond this and also include, but not be limited to, an e-learning platform, an operational tool, a repository for research information and a tool for linking a diverse range of stakeholders. To avoid pitfalls when designing this system, it is necessary to be aware of and learn from the many unsuccessful implementations using ICT for development, whether or not these failures are documented in the public domain. Local involvement is one important lesson, which presents the challenge of building a scalable system without a top-down bureaucracy. A system of this nature could be a viable option for mobilising many unemployed youths and provide them with career paths, starting with simple collection activities. Opportunities for promotion to more skilled areas of activity should be available, following completion of prescribed training, using ODL via the portal. Using transparent career paths that encourage the more disadvantaged to advance to higher skilled jobs, this system would avoid the exacerbation of the rich-poor divide, often associated with technological innovations [28].

4. ICTs FOR HORIZONTAL EXCHANGE OF INFORMATION TO EXPAND THE KNOWLEDGE BASE

Smallholder farmers are frequently locked into unsustainable production systems as a result of limited access to information and other knowledge resources, assets and markets, as well as through inadequate recognition of the value of traditional knowledge [10]. This information access gap prevails, despite what should by now be widespread awareness of the links between scientific knowledge, the environment, the economy and institutions:

> *'A society develops economically as its members increase jointly their capacity for dealing with the environment. This capacity for dealing with the environment is dependent on the extent to which they understand the laws of nature (science), on the extent to which they put that understanding into practice by devising tools (technology), and on the manner in which work is organized'[29].*

Relevant for society in general, the above quote, by Walter Rodney from 1972, is just as applicable today for the trajectory to agro-ecological farming, which is highly knowledge-intensive. While extension services are a common and useful way of disseminating information about new farm practices, they can be quite labour intensive and often not suitable for women [30][31]. This is a particular problem with the feminisation of agriculture in the developing world, as in many countries men migrate for employment opportunities in urban areas and other countries to a greater extent than women [32]. ICT is by no means a panacea to learning about the environment, particularly for women. Studies have shown that they have for various reasons been excluded from many ICT initiatives [33] and where they have been included, women might have found them empowering without necessarily gaining economic benefits [34]. Better understanding of the reasons for these outcomes and how they can be mitigated, or identification of other suitable ways in which women can improve their knowledge in this area, is a precondition for the realisation of the proposed initiative.

ICT has been used extensively for farmer education, initially in the form of radio and more recently through other media, primarily mobile phones. The use of recorded voice and video, rather than relying on text on mobile devices could overcome constraints stemming from low literacy levels and the lack of localisation of scripts on mobiles. When accessed through mobile phones, mLearning can make relevant applications accessible in a timely manner for farmers - e.g. they can diagnose plant diseases by comparing pictures available through MMS with what they see in their fields. But such applications are sometimes unaffordable for those who could benefit from them most, and ways must be found to overcome this impediment, e.g. through universal access policies and/or other subsidies.

With the emergence of open access scientific publishing and open educational resources (OER), an increasing amount of useful and educational material for teaching and learning agricultural skills is, and will become more widely available in the public domain, reducing the costs of preparing content, but nevertheless requiring local involvement for tailoring and/or re-purposing [35]. ODL and OER do not necessarily mean that farmers should be left to their own devices to locate, access and interpret these resources. Learning alone at home, the way ODL for higher education is usually implemented in the developed world, is rarely possible and probably not an appropriate learning approach in rural areas in developing countries, due to low literacy skills, inadequate equipment and electricity supply constraints. Blended learning, combining ODL material with group learning, is becoming a popular mode of knowledge acquisition, not only to overcome resource constraints, but also because of the benefits of learning in a group environment. This raises the issue of appropriate venues and support services that go beyond mere connectivity measures and content creation, taking into account all variables necessary for learning.

The importance of disseminating agricultural information for sustainable rural development to enable farmers to learn new methods is well recognised, but less acknowledged is the value inherent in multi-directional communication, particularly between farmers, researcher and policymakers. In such horizontal exchange of information, all participants in the dialogue are both senders and receivers of valuable information. It is as important for those with scientific expertise in this field to know how to impart this to farmers as it is for the latter to know how and where they can find out what they need to know, obtain relevant learning material, make enquiries and feed their experiences into the knowledge chain. As argued by the World Bank [36], agricultural development depends to a great extent on how successfully

knowledge is generated, shared and applied, and for that, interactive and collaborative forms of sharing and exchange are required [37]. ICTs can only facilitate, but not encourage, coordinate or implement, complementary use of different knowledge sources to bring about the continuous process of innovation that is so vital in driving this sub-sector, and at the same time bridge social and geographical distances.

There are several examples of such information exchanges, one of which is the Bulgarian network of sustainable education and permaculture initiatives. With most members located in remote rural and mountainous areas, activities are mainly conducted online [38]. Another example is a project in the South Pacific, where promotional DVDs were used for training in low-cost irrigation systems, composting and the use of neem and derris as organic pesticides. This production was one output from extensive collaboration between diverse information providers and community groups, including farmer groups [39]. Open access to research findings can also be beneficial, both in communicating research findings and in giving developing country researchers a voice and, thereby, providing appropriate information for developing country agriculture. The case of Prof. Mary Abukutsa-Onyango of Jomo Kenyatta University of Agriculture and Technology, whose research on African Indigenous Vegetables (AIV) only found a voice in open access journals in Africa, is instructive. She attests to the importance of open access publishing for development in African countries [40]. In all of the above examples, ICT is a fundamental enabler, but it is only one of the ingredients required for information exchange.

All parties in an agriculture value chain can benefit from the use of ICT in the marketing of agro-ecological produce. While the usefulness of ICT's for market price information, particularly by farmers to reduce the information asymmetry between them and traders has been recognised [37],[41], it has also been acknowledged that information is not sufficient to change power relationships and often has to be supplemented with access to other resources. These must go hand in hand with the information, as there is no point in a farmer knowing that a better price could be obtained at a market 50 km away, in the absence of transport to get to the market. Similarly, awareness that prices will be much higher six months after the harvest is useless for a farmer lacking storage facilities or having to pay back a loan obtained to purchase seeds. Against this, it has been posited that the mere increase in information symmetries can weaken the bargaining position of intermediaries and assist farmers in making better decisions [42].

Buyers and sellers at the extremes of the supply chain usually do not interact directly, but via one or several intermediaries. The role of intermediaries, particularly in the agriculture supply chain, has been the subject of divergent views and evidence in the ICT literature. There seems to be general consensus that wider access to ICTs can erode information asymmetries, but there is contention about what this means in practice. While it potentially enables farmers to increase their surplus, which can be used for productive investments on their farms to generate higher yields, this is not always the outcome. ICT has led to some disintermediation among farmers and micro-enterprises [43],[44], but, there is also evidence pointing to ICTs fostering ongoing and even the entrenchment of intermediation [45],[46],[47]. Intermediaries can play productive as well as exploitative roles in the agriculture chain and by facilitating transparency, ICT can contribute to more productive relationships [48], but cannot by itself change power balances.

Transparency is critical in building confidence and trust in a supply chain and this is especially so regarding claims relating to organic agriculture. The current limited ability to track produce from source to destination could affect the level of trust when it comes to purchasing organic produce. ICT based tracking systems could overcome this constraint. It is not suggested that outputs from such practices necessarily be marketed under the stringent conditions required for organic certification. Aiming to produce to higher standards has inherent benefits as it can induce efficiency and stimulate innovation, which in turn can enhance competitiveness in the global agriculture market [10]. It has been difficult for farmers in developing countries to enter the global agriculture market because of national food security and farm trade policies, which historically have tended to favour producers from developed countries. Global trade in agriculture got more complicated with the rise in food prices in 2007-2008, when several countries restricted the export of staple foods to protect domestic consumers. Whatever the trading environment (the complexities of which are beyond the scope of this paper), ICT is necessary, but by no means sufficient, to facilitate entry to the global market.

5. WHAT TYPE OF ICTs

Farmers tend to gain information and communicate through a variety of methods and technologies. The rapid growth of mobile devices holds great potential for greening the farming sector, but may be less useful where scripts have not been localised for mobile phones or networks. A range of ICTs must therefore be considered, primarily for educational purposes, and much experience has already been gained from community radio, which continues to play a vital role, having been pioneered by the Food and Agriculture Organization (FAO) several decades ago. The FAO has also pioneered the "e-Agriculture Community" forum, a global community of practice for the exchange of information, resources and ideas related to the use of ICT for sustainable agriculture and rural development. As the website is only in English, French and Spanish, it seems to be targeted at intermediaries and researchers, rather than farmers. Television, the take-up of which is increasing in rural areas with electrification, is another potential medium for disseminating information about sustainable organic agriculture to farmers. These and other market based information dissemination channels may require incentives or possibly some form of regulation to respond to this challenge, as privately owned media relying on revenue from commercials might face opposition from companies operating in the agrochemical sector.

Personal computers, laptops and tablets are other useful instruments for disseminating information and communicating about sustainable agriculture. As these would be unaffordable for the majority of farmers, both in terms of up-front and operational costs, particularly where there is limited access to electricity, some form of community ICT access point for shared access may be desirable. Multipurpose community telecentres, which since the 1990s have been one model for sharing access, are an avenue through which information can be disseminated and exchanged. Driven by public institutions and NGOs, rather than the market, their success has been mixed, and their potential to contribute to development has not always been realised. There are several reasons, including of a formative nature, such as inability to maintain equipment and pay for services when external funding

ceases. It is critical to better understand why this is so often the case and to explore outcomes from a summative perspective, before making further investments in this type of facility.

An important question to consider is whether telecentres can be given a new lease of life, focusing on agro-ecological agriculture and add community radio to the mix of media, which some of them already do, through which they disseminate agricultural and other information. While community radio is not as efficient for multi-directional exchange of information, it has the benefit of reaching women who tend to have underused telecentres, compared to men [49]. But if telecentres are to be used for this purpose, they must exert greater effort in attracting women, not only for reasons of fairness and equality, but also because women are playing an increasingly important role with the feminisation of agriculture. Highlighting the significance of ICTs for information sharing in agriculture, FAO [50] noted that locations where ICT can be accessed must be suitable, particularly for women. As important as the locations, is what occurs at them, and a key benefit of this type of institution is that they often have infomediaries, who can assist those with insufficient literacy levels to access relevant information.

Aware of local information needs, where to obtain and how to access relevant information, telecentre infomediaries can act as knowledge brokers for sustainable agriculture practices. But it can also be disempowering for farmers to have to go via intermediaries to access information, so they should not be substitutes for training and self-learning. In addition to being a location for accessing information, telecentres are places for interaction and engagement. Sometimes represented as obsolete with the emergence of the almost ubiquitous mobile networks, Pant & Heeks [51] suggested a new role for them, combined with mobiles, in enlisting ICTs to deal with climate change, particularly when accompanied with deliberate development of capacities. However, unlike the other modes of implementing technologies (e.g. broadcasting and individual ownership of mobiles that can easily and quickly reach a large number of people) this is not the case for telecentres, which have not managed to scale to a significant extent, despite a large number of pilots.

In addition to access methods, it is important to look at the platforms for the different applications, whether for the commercialisation of organic input, learning or marketing. In doing so, account must be taken of the diverse ways in which users will access a range of applications for obtaining information and communicating. This calls for greater interaction between the development of ICT hardware, software and systems on the one hand, and users of agro-ecological practices on the other, to address the compounded challenges of access difficulties, low literacy rates and affordability.

Even more important is access to content. There is a strong movement towards making the results of publicly funded research openly and freely available, with research agencies, funders and governments increasingly mandating open access [52],[53]. Not only does this enable access to worldwide research from developing countries, it also enables the reverse flow of research and information from developing countries [54]. With open access, there is greater prospects for knowledge in this field to reach places where it can be put to good use and, in turn, further developed. But open access is not enough, concerted action is required to make the scientific research understandable by farmers and to establish bidirectional channels between farmers and researchers. Such communication could be quite problematic, whether due to language or lack of relationships beyond the boundaries where scientists and farmers, respectively operate.

Beyond availability and access, adoption and use of ICTs must also be addressed, particularly with respect to what knowledge is required to use various ICTs and how content should be presented to make it understandable. To gain a better understanding of this process, social theories dealing with this issue can provide useful insights into potential barriers and implications, if barriers persist - e.g. theories dealing with diffusion of innovations, structuration and knowledge gap theories [55]. Awareness of impediments and how to overcome them, as informed by such theories, particularly when applied to developing countries, is essential to avoid the implementation of systems that will not be used. Reference to the design-reality-gap [56] framework can provide a useful guide for this purpose.

6. ENABLING CONDITIONS AT THE MACRO-LEVEL

Despite what appears to be a reasonable rationale of agro-ecological practices, a transition to this type of farming is unlikely to materialise on its own, without intervention, particularly as vested interests could try to inhibit such a conversion. Policy intervention is both necessary and desirable where the market fails to pay for negative externalities and for initiatives with overriding social objectives. There is also the issue of acceptance by potential users, which even if new practices are beneficial, cannot automatically be assumed, as illustrated in literature dealing with innovations [57]. It is therefore necessary to work on acceptance in parallel with the up-scaling of the sub-sector, which, although not being a ”big-bang” approach, nevertheless has to move at a rapid rate to maximise the opportunity for climate change adaption and mitigation.

While implementations must be receptive to national and local idiosyncrasies, it is nevertheless useful to discuss some general principles.

There is likely to be a process of bargaining between the parties involved in existing and future agricultural supply chains, including existing suppliers of chemical inputs, farmer representatives, scientists, the various tiers of government and NGOs, as well as international and foreign aid agencies. One model through which conflicting interests could be managed would be interactive policy-making, in which various parties are actively involved in jointly arriving at a decision [58]. ICTs are important in such a co-design process.

Ultimately, governments have mediation and policy formulation responsibilities in such a process and they have at their disposal policies of an enabling and/or coercive nature. While both have their place in different climate change policy contexts, enabling polices would be the most efficient and equitable approach for agro-ecology, as they are more likely to generate trust in government institutions and commitment by farmers to embrace new practices. Trust is often a critical component in adoption of innovations. Coercive measures, such as charges to internalise the environmental costs of conventional agriculture, while appropriate for large-scale commercial farms, would be inappropriate for small-holder subsistence agriculture, as they would impose unnecessary hardship. It would in any case be very difficult, if not impossible, to implement such policies administratively. Enabling policies can provide incentives for organic farming as well as disincentives for conventional agriculture (e.g. by removing

subsidies on chemical inputs). Some agricultural subsidies exacerbate the negative effects, as they tend to encourage overuse, particularly of inorganic fertilisers, with detrimental effects on the environment [11], as well as exposing governments engaging in such subsidies to oil price increases. Instead, governments could offer subsidies for organic fertilisers and compensate for the lower yields during the transition phase.

The enabling environment must take account of the interconnected dimensions of sustainable agriculture, food security, climate change, poverty reduction, and information systems to support the governance of sustainable agriculture. This requires collaboration across different government functional areas. Such overlap of ICT with other policy domains was recognised by Mansell and Wehn [1] in their 1998 book on ICT for sustainable development. If done appropriately, it could serve to strengthen the role of small-holders and those who are most marginalised, by providing them with a safety-net in the emerging sector of organic input production.

The livelihood outcomes as represented by improved food security and other features of well-being expected from such an initiative depend on awareness, and capacity. While ICT can facilitate these, improved livelihoods are also required to enable the use of ICTs, both in terms of skills and affordability. This points to the importance of incorporating ICT training with training in use of agro-ecological methods. This requires collaboration between government authorities responsible for ICT and farming.

Other institutions critical to the enabling conditions relate to finance. Whether secured by the public sector through inclusion in the fiscal framework or other sources, its provision must encourage self-sufficiency, rather than contributing to dependencies through increased farmer indebtedness, to facilitate the long term viability of sustainable agriculture, beyond the expiry of external assistance. Potential funders outside governments can include NGOs, commercial firms and/or other agencies acting as donors or lenders, including environment related funds, such as the Clean Development Mechanism (CDM) and Payment for Environmental Services (PES). While funding from carbon trading sources can have considerable administrative overheads [59], it is an opportunity worth pursuing. In order to avoid the paradox of having to demonstrate carbon sequestration before receiving funding, but unable to do so due inadequate funding of the type of facility proposed in this paper, it may be necessary to bring forward the "green investment" in anticipation. Learning from funding of social programmes in general, it seems that diversity of funding is preferable to funding from a single source, as this tends to encourage more champions and community support [60] and would also reduce the reliance on a single funding source. ICT could be useful, at least in starting this process, by enlisting support from the public (e.g. through awareness).

7. A RESEARCH AND EVALUATION AGENDA

The impact of innovations, such as the one proposed in this paper, need to be evaluated in terms of their environmental and social objectives and researchers play an important role in the evaluation of pilot and wider implementations, through formative and summative evaluations. Initially, such research could be conducted on existing operations in this area (e.g. the Bangladeshi Waste Concern, mentioned in section 3). Firstly, it has to be established that there are net environmental benefits from such operations. This could be done through an environmental value chain analysis (i.e. comparing the environmental costs at each stage of the process with environmental costs of producing and using conventional inputs). Secondly, research should also be conducted on how ICT is used and could be better used by different stakeholders in such enterprises. The research should extend to explore benefits achieved by various parties involved in this chain and any unintended negative consequences for the most vulnerable population or the environment.

Research should also explore whether there are indeed any symbioses between agro-ecological practices and livelihood improvements, using a wide range of social and economic indicators, including the role of different types of ICTs in contributing to outcomes, drawing and expanding on existing research in this field. This would include exploring how different design and implementations of ODL resources affect learning outcomes that lead to adoption of more climate compatible practices among farmers,

Another area for fruitful research would be to investigate the market for external inputs into organic farming in developing countries, focussing on constraints faced by this sector and identifying whether and how ICTs could contribute to overcoming these. The results are likely to be highly contextual to different country settings and show differences within countries. Empirical insights about the conditions under which the potential of ICTs can be realised to contribute to scaling up agricultural inputs for organic farming in a way that reduces poverty will be an important input to governments seeking to direct their policy efforts into agro-ecological farming. It will also be necessary to tune into the interests of policy-makers and funders when formulating a detailed research agenda in a specific contexts.

The next step would be to capture the disparate components of this paper into a cohesive framework. The sustainable livelihoods approach (SLA) could provide a conceptual framework within which the diverse aspects of such an agro-ecology initiative could be brought together under one umbrella. This framework is '*a way of thinking about the objectives, scope and priorities for development. In essence it is a way of putting people at the centre of development, thereby increasing the effectiveness of development assistance*' [61] The SLA explores livelihood resources and strategies that enable or constrain the achievement of sustainable livelihoods for different groups and institutional processes. At the core of this concept are the tangible and intangible assets (physical, natural, financial, human, and social) of firms, communities and individuals and their ability to withstand shocks in environments that make them vulnerable. When used for interventions, the SLA has a holistic rather than sectoral focus, and is thus suitable for incorporation of ICT as an integral component, as reflected in a number of ICT related studies adopting this framework [62]. It can be applied in conjunction with a diverse range of research and evaluation methodologies used for international development, both qualitative and quantitative (e.g. randomised control trials).

The SLA is not without its critics, who have identified deficiencies in the approach relating to insufficient attention to the macro-level, private and economic institutions, its overemphasis on self-help and in defining and measuring the capital types and sustainability [63],[64]. These shortcomings could be overcome when applied in practice, as the framework can be extended to incorporate the missing ingredients, particularly poverty reduction

and the macro-level, both of which are critical for the success of such climate change adaptation and mitigation initiatives. It could be designed to analyse outcomes and to understand existing and evolving formal and informal constraints at the micro-, meso- and macro levels in several domains, including the environmental, technical, institutional, political and social in a combined rather than fragmented view of the entire system. In addition to these wider system components, the business performance of this sub-sector, in terms of triple bottom line achievements, must also be monitored to facilitate a consistent stream of funding.

8. CONCLUDING REMARKS

It is now widely recognised that "business as usual" in the farming sector will not bring food security, poverty reduction and environmental sustainability due to the combination of intensified pressure from population growth, unsustainable use of resources and climate change. But any changes must be compatible with improved livelihoods for small-holders, rather than at their expense. Consensus among a diverse range of agencies is now crystallising around the idea that agro-ecological farming is pointing the way towards meeting the dual objectives of climate change adaptation/mitigation and poverty reduction.

The scaling up of organic input to the agricultural sector in developing countries is one avenue for facilitating such a transformation of the food production process. While it would not, on its own, encourage the take-up of agro-ecological practices or reduce rural poverty, it could be an important ingredient in a mix of policies. If implemented appropriately, it has the potential of providing employment around which a safety-net could be constructed for landless villagers and poor small-holders, who could supplement their incomes through involvement in activities associated with organic input production. It could thus be one pathway to climate change adaptation and mitigation with poverty-reduction prospects, targeted at achieving human development objectives. As a new undertaking, it is easier for traditionally excluded populations, particularly women, to be included, as this new activity could be designed to avoid invoking constraints characterising traditional roles, such as being saddled by existing gender labour divisions. But many farmers, often struggling for survival, are likely to require incentives, support and further training before they are ready to abandon their current agricultural practices.

The embryo of an idea outlined in this paper requires further research and other work, but this should not be a reason for delaying action. While contested in terms of productivity per area cultivated, there is already sufficient evidence to show the benefits of agro-ecological practices for climate change adaptation/mitigation and human development. Evaluation of implementations to assess the extent of contributions to human development (e.g. in terms of poverty reduction, health and gender equality as well as to the environment) should be conducted on an on-going basis, providing lessons on what does and does not work in different contexts and how to overcome problems. An inventory of best practice in this area could then be produced from these lessons.

ICT cannot be a driver of this process, but this paper has provided a working hypothesis of how ICT could be an enabler, facilitating the various steps in the process towards one type of climate change adaptation and mitigation policy in agriculture. It can be used extensively in the establishment of a new sub-sector, for training, exchanging information as well as for interactive policy-making. Provided the focus is on those who are more marginalisesd, it might be possible to avoid a situation where the initiative benefits only the more prosperous members of society, as has sometimes been the case with climate change projects in the developing world. In outlining the potential of various forms of ICTs, the paper emphasised that rather than limiting attention to physical infrastructure and software platforms, emphasis must also be placed on more open access to information and abilities to absorb it. In addition, affordability and skills to use various technologies should be given adequate consideration. While knowledge, transparency and efficiency, facilitated by ICT, would minimise the danger of the deployment of a low-risk initiative of this nature becoming a costly failure, many policy and institutional hurdles must be overcome to achieve these to a sufficient extent.

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10. REFERENCES

[1] Mansell, R. & Wehn, U. 1998. *Knowledge societies: information technology for sustainable development*. Oxford University Press: Oxford

[2] World Bank, 1998. *World Development Report 1998/99: Knowledge for Development*. Washington, DC: World Bank and Oxford University Press. DOI : 10.1596/978-0-19-521118-4

[3] Hilty, L. M. and Ruddy, T. F. 2010. Sustainable development and ICT interpreted in a natural science context. *Information, Communication & Society, 13*(1), 7–22. DOI=http://dx.doi.org/10.1080/13691180903322805

[4] WSIS - World Summit on the Information Society. 2003. *Geneva Plan of Action*. http://www.itu.int/wsis/docs/geneva/official/poa.html

[5] UNICT – United Nations ICT Task Force. 2003. *Tools for development: using information and communications technology to achieve the Millennium Development Goals*. Working paper. http://www.apdip.net/projects/2003/asianforum/

[6] Rio 20+. 2012. *The Future We Want*. http://www.uncsd2012.org/content/documents/727The%20Future%20We%20Want%2019%20June%201230pm.pdf

[7] Houghton, J. 2009. *ICT and the environment in developing countries: opportunities and developments*. Paris: OECD. http://www.oecd.org/dataoecd/40/25/43631894.pdf.

[8] Commission on Sustainable Agriculture and Climate Change. 2012. *Achieving food security in the face of climate change: final report.* Copenhagen, Denmark. www.ccafs.cgiar.org/commission.Commission on Sustainable Agriculture and Climate Change. 2012. Achieving food security in the face of climate change.

[9] Intergovernmental Panel on Climate Change. 2007. Summary for policymakers. In: *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the*

Intergovernmental Panel on Climate Change, 7-22. Cambridge University Press: Cambridge.

[10] United Nations Environment Programme. 2011. *Towards a green economy: pathways to sustainable development and poverty eradication.* www.unep.org/greeneconomy.

[11] World Bank. 2012. *Inclusive green growth: the pathway to sustainable development*. Washington, D.C. World Bank.

[12] De Schutter, O. 2010. Report submitted by the Special Rapporteur on the right to food. UN General Assembly, Human Rights Council, 16th session, agenda item 3.

[13] OECD. (2012). *Evaluation of Agri-Environmental Policies: Selected Methodological Issues and Case Studies*. OECD Publishing. http://dx.doi.org/10.1787/9789264179332-en

[14] Uvin, P., Jain, P. S. And Brow, L.D. 2000. Think large and act small: toward a new paradigm for NGO scaling up. *World Development, 28*(8), 1409 – 1419.

[15] International Fund for Agricultural Development. 2010. *Rural poverty report 2011. New realities, new challenges: new opportunities for tomorrow's generation*. Rome: IFAD.

[16] Kilcher, L. 2007. How organic agriculture contributes to sustainable development. In H. Willer & M. Yussefi (Eds.) *The world of organic agriculture - statistics and emerging Trends*. Bonn: International Federation of Organic Agriculture Movements (IFOAM).

[17] Niggli, U., Earley, J., and Ogorzalek, K. 2007. *Issues paper: organic agriculture and environmental stability of the food supply*. Prepared for International Conference on Organic Agriculture and Food Security, Food and Agriculture Organization of the United Nations, Rome.

[18] International Assessment of Agricultural Knowledge, Science and Technology for Development. 2009. *Agriculture at a crossroads: global report*. Washington, DC: Island Press.

[19] United Nations Department of Economic and Social Affairs. 2011. *World economic and social survey 2011: the great green technological transformation*. New York: United Nations.

[20] Jensen, H.K., Konradsen, F., Jørs, E., Petersen, J.H., and Dalsgaard, A. (2011). Pesticide use and self-reported symptoms of acute pesticide poisoning among aquatic farmers in Phnom Penh, Cambodia. *Journal of Toxicology*, 1–8. Doi:10.1155/2011/639814

[21] Naidoo, S., London, L., Burdorf, A., Naidoo, R., and Kromhout, H. 2008. Agricultural Activities, Pesticides Use and Occupational Hazards Among Women Working in Small-scale Farming in Northern KwaZulu-Natal, South Africa. *Int. J. Occup. Env. Heal.,14*(3), 218-224.

[22] United Nations Conference on Trade and Development & United Nations Environment Programme. *Organic Agriculture and Food Security in Africa*. New York and Geneva: United Nations

[23] Seufert, V., Ramankutty, N. & Foley, J. 2012. Comparing the yields of organic and conventional Agriculture. *Nature, 487*, 229-234. Doi:10.1038/nature11069

[24] Kim, C-G and Banfill, J. 2012. A policy evaluation of Environmentally Friendly Direct Payment Programme in Korea. In OECD, *Evaluation of Agri-Environmental Policies: Selected Methodological Issues and Case Studies, pp. 153-167*. OECD Publishing. OECD Publishing. http://dx.doi.org/10.1787/9789264179332-en

[25] Jones. R. 2010. Green Harvest. *A history of organic farming and gardening in Australia*. Collingwood, Australia: CSIRO.

[26] Zurbrügg C., Drescher S., Rytz I., Sinha AHM, Enayetullah I. 2005. Decentralized composting in Bangladesh, a win-win situation for all stakeholders. *Resources, Conservation and Recycling, 43*(3), 281–292. Doi:10.1016/j.resconrec.2004.06.005.

[27] Rashid, S. Z. 2011.Composting and Use of Compost for Organic Agriculture in Bangladesh. *Proceedings of the 4th International Conference for the Development of Integrated Pest Management in Asia and Africa* (20-22 January 2011)

[28] Gerster R and Zimmermann S. 2005. *Up-scaling pro-poor ICT-policies and practices: a review of experience with emphasis on low income countries in Asia and Africa*. Berne: Swiss Agency for Development and cooperation and M S Swaminathan Research Foundation.

[29] Rodney, W. 1976. *How Europe underdeveloped Africa*. London: Bogle-L'Ouverture Publications. Original 1972.

[30] Tandon, N. 2010. New agribusiness investments mean wholesale sell-out for women farmers. *Gender & Development, 18*(3), 503 – 514. DOI =http://dx.doi.org/10.1080/13552074.2010.

[31] Moussa, M., Wen, Y., Wu, H., Diakite, M., GERSON, K., and Wang, H. 2011. Impact assessment of women farmer activity on poverty reduction and food security: a case of Kindia region/Guinea. *Journal of Agricultural Science*, 3(4), 141- 150. http://journal.ccsenet.org/index.php/jas/article/view/9342.

[32] Deere, C.D. 2005. *The feminization of agriculture? Economic restructuring in rural Latin America*. Occasional Paper 1. Geneva: United Nations Research Institute for Social Development.

[33] Siyao, P. O. 2012. Barriers in accessing agricultural information in Tanzania with a gender perspective: the case study of small-scale sugar cane growers in Kilombero District. *The Electronic Journal of Information Systems in Developing Countries, 51* (6), 1-19.

[34] Huyer, S. and Sikoska, T. 2003. *Overcoming the gender digital divide: understanding ICTs and their potential for the empowerment of women*. INSTRAW Research Paper Series No. 1. http://www.un-instraw.org/pdf/oth-Synthesis

[35] Latchem, C. (2012). *Quality assurance toolkit for open and distance non-formal education*. Vancouver: The Commonwealth of Learning.

[36] World Bank. 2007. *Enhancing agricultural innovation: how to go beyond the strengthening of research systems*. Washington, DC: The World Bank.

[37] Ballantyne, B. 2009. Accessing, Sharing and Communicating Agricultural Information for Development: emerging trends and issues. *Information Development, 25*(4), 260-271. DOI= 10.1177/0266666909351634.

[38] Association for Progressive Communications & Hivos. 2010. Global information society watch 2010: ICTs and

environmental sustainability. http://www.giswatch.org/sites/default/files/gisw2010_en.pdf

[39] Hunter, D. 2007. Improving production and accessibility of agricultural information through capacity-building, networking and partnerships in the South Pacific. *International Journal of Education and Development using Information and Communication Technology, 3*(3), 132-135.

[40] Abukutsa-Onyango, M. 2010. Prof. Mary Abukutsa-Onyango discusses the importance of Open Access for research from Kenya and other African countries. Interview was recorded on Feb. 19th, 2010 at the University of Nairobi during a Workshop on Increasing the Impact of Research through Open Access, co-hosted by the University of Nairobi Library, eIFL.Net and Bioline International. http://vimeo.com/10169351.

[41] Rashid, A. T. & Elder, L. 2009. Mobile phones and development: an analysis of IDRC supported projects. *The Electronic Journal on Information Systems in Developing Countries, 36(2*), 1–16.

[42] Bedi, A. S. 1999. The role of information and communication technologies in economic development: a partial survey. Discussion paper on development policy, no. 7. Bonn: Center for Development Research (ZEF). http://www.zef.de/fileadmin/webfiles/downloads/zef_dp/zef_dp7-99.pdf.

[43] Bayes, A. 2001. Infrastructure and rural development: insights from a Grameen bank village phone initiative in Bangladesh. *Agricultural Economics, 25*(2/3), 261–272. DOI: 10.1111/j.1574-0862.2001.tb00206.x.

[44] Bowonder, B., Gupta., V., and Singh, A. 2003. Developing a rural market e-hub: The case study of e-Choupal experience of ITC". Planning Commission of India. http://planningcommission.nic.in/reports/sereport/ser/stdy_ict/4_echoupal%20.pdf.

[45] Duncombe, R. and Heeks, R. 2001. Information and communication technologies and small enterprise in Africa: lessons from Botswana. Institute for Development Policy and Management, University of Manchester.

[46] Jagun, A., Heeks, R. and Whalley, J. 2008. The impact of mobile telephony on developing country micro-enterprise: a Nigerian case study. *Information Technologies and International Development, 4*(4), 47–65.

[47] Overå, R. 2006. Networks, distance and trust: telecommunications development and changing trading practices in Ghana. World Development, 34 (7), 1301–1315.

[48] Dixi, G. and Jayaraman, N. 2011. Strengthening agricultural marketing with ICT. In The World Bank/InfoDev'ARD, ICT in agriculture: connecting smallholders to knowledge, networks, and institutions. Module 9, pp.205-237. Washington, DC: World Bank.

[49] Kumar, R. and Best, M. 2006. Social impact and diffusion of telecenter use: a study from the sustainable access in rural India project. *The Journal of Community Informatics, 2*(3),online.

[50] Food and Agriculture Organization. 2011. *The state of food and agriculture. Women in agriculture: closing the gender gap for development*. Rome: FAO.

[51] Pant, L.M. & Heeks, R. 2011. ICT-enabled development of capacity for climate change adaptation. Centre for Development Informatics, Institute for Development Policy and Management, University of Manchester.

[52] Bailey, C.W. 2010. Transforming Scholarly Publishing through Open Access: A Bibliography, available athttp://digital-scholarship.org/tsp/w/emerging.htm.

[53] Open Access Scholarly Information Sourcebook: http://openoasis.org/index.php?option=com_content&view=article&id=146&Itemid=253.

[54] Chan, L. 2011. Knowledge and communication for development: an online course (IDSB10H) offered at the University of Toronto Scarborough. http://vimeo.com/29036355.

[55] van Dijk, J. and Hacker, K. 2003. The digital divide as a complex and dynamic phenomenon. *The Information Society, 19*(4), 315–326. DOI: 10.1080/01972240309487

[56] Heeks, R. 2003. Most eGovernment-for-development projects fail: how can risks be reduced? iGovernment Working Paper Series, paper no. 14, Institute for Development Policy and Management, University of Manchester.

[57] Rogers, E. M. 2003. *Diffusion of innovations* (5th ed.). New York: Free Press. First published in 1962.

[58] Driessen, P. P.J, Glasbergen, P., and Verdas, C. 2001. Interactive policy-making - a model of management for public works. *European Journal of Operational Research*, *128*(2), 322 – 337.

[59] Stabinsky, D. and Ching, L.L. 2012. Ecological agriculture, climate resilience and a roadmap to get there. Penang: Third World Network.

[60] Savaya R. and Spiro, S.E. 2012. Predictors of Sustainability of Social Programs. American Journal of Evaluation, 33(1), 26-43.

[61] Department for International Development. 1999. Sustainable livelihoods guidance sheets. http://www.eldis.org/vfile/upload/1/document/0901/section2.pdf.

[62] Chapman, R., Slaymaker, T. and Young, J. 2004. *Livelihoods approaches to information and communication in support of rural poverty elimination and food security: the literature update*. London: Overseas Development Institute.

[63] Albu, M. 2008. Making markets work for poor - Comparing M4P and SLA frameworks: Complementarities, divergences and synergies. Swiss Agency for Development and Cooperation. http://www.springfieldcentre.com/publications/sp0803.pdf.

[64] Toner, A. and Franks, T. 2006. Putting livelihoods thinking into practice: implications for development management. *Public Administration and Development, 26*(1), 81–92.DOI: 10.1002/pad.395