《研究ノート》

# Environmentally Friendly and Sustainable Agriculture and the Role of Innovation

**Celia L. Umali**

**Abstract**

The aim of this paper is to investigate how agricultural innovation can be applied to achieve the triple bottom line of agricultural sustainability, environmental sustainability and improved welfare. The different perspectives on the different forms of agricultural technology are discussed. Technological innovation in agriculture that would not only increase the economic returns to farmers but can also make farming done in a sustainable way and at the same time conserve the environment keeping in mind that agriculture, a natural resource-based industry, is contingent on how we protect and conserve the environment is dealt with.

**Keywords:** agricultural innovation, sustainability, environment

What lies ahead for agriculture is conditional on how we conserve our natural resources on which agriculture depends. The agenda of food security for everyone now and in the years to come would not succeed unless our natural resources—land, water and forests—are protected and conserved. Although the contribution of the agricultural sector to the economies of many countries has declined in favor of the industrial and service sectors,

the agricultural sector can not be neglected. Food is a basic necessity so it is important to ensure that everyone has access to sufficient, safe and nutritious food, given the rapidly growing population. Food security has not only economic but social and political implications as well. In case of food shortages, among others, it is usually the low income people specially in the developing countries who suffer the most. When people are hungry there will be social unrest and discontent and eventually political instability. Thomas Malthus' theory states the world's population is growing geometrically while food yield is growing arithmetically and he had this to say: " The power of population is indefinitely greater than the power in the earth to produce subsistence for man " [1]. In order to meet the increasing food needs of an ever growing population, the trend that goes back many years was continual expansion in the land allotted for cultivation. However this trend has changed due to increasing urbanization and industrialization in many countries that more farm lands are now being converted to residential or commercial / industrial areas leaving less land for cultivation or if there are land available they are not arable. The main source of growth in agriculture therefore is increase in productivity, meaning, yield per given area has to improve. However agriculture being a resource and climate dependent industry impediments and uncertainties to increasing productivity prevail. How then can science and technology alleviate these problems given the scarcity of resources and at the same time keep our environment pristine that is important to sustain agricultural production? The aim of this paper is to study the relationship between agriculture, sustainability and the environment and the role innovation plays.

## Economics of agriculture

In developing countries 70-80% of the family budget is spent on food. Recently however there is a rising middle class in many developing economies so much so that their food needs are now slowly converging with those in the developed countries. The consumers demand is fast changing with shift in consumption behavior to more valued added food that have more dietary and health benefits. Hence this shift in consumer attitude towards more valued added food offers economic opportunities not only for producers of the commodity per se but for the value creating agroindustry which should be able to tap into these fast changing consumer taste and preferences, both in the domestic and international fronts. A balance in the production of staple foods as well as more value added goods has to be kept. These demand factors though have to be noted are governed by income elasticitiy of demand. Engel's law states that as income in developing countries increases the demand for staple food like rice, potatoes and maybe fish increases for some time but then declines as income continues to increase and instead consumers will buy more meat, fruits, cheese ad other high value added goods.

Likewise, economic growth in many developing countries though means that people have more money to buy food to the extend that demand outstrips supply. This together with uncertainties in weather conditions had led to increase in prices of agricultural commodities. The International Fund for Agricultural Development (IFAD) reported in March 2008 that the price of rice increased by 32%, corn 74%, soy bean 87% and wheat 130% compared to the previous year. The big demand for meat and feeds in the fast growing economies of China and India for instance has contributed much to the price increase due to demand-supply imbalance. Similarly, corn in the

US is now used to produce ethanol which has driven up the price of corn feeds in the world market. Increase in oil prices, disequilibrium between supply and demand, use of corn and sugar as alternative fuels, uncertainties in weather as well a speculation have driven up the prices of food. In the first quarter of 2011, the World Bank disclosed that compared to 2010, food prices have gone up 29%. In many developing countries, inflation has caught up with food prices, referred to as agflation and is affecting the lives of the low income people.

Beyond the farm, agriculture production forms part of the supply chain of agro-industries. Due to the perishability and short shelf life of farm products, value creation in the form of processing of agricultural products provide the farmer and processor good economic returns not to mention the rural employment benefits and income to non-farm workers. Capitalizing on the nation's comparative advantage, many countries have dual agricultural economies, namely the traditional crops or staples used for food like rice, corn, wheat and tea, and the non-traditional crops such as seafoods, vegetables, cut flowers and high valued processed food items geared for the global market and are a good source of foreign exchange currency.

## Unique characteristics of agriculture

Given the above, the importance of agriculture can not be underemphasized. Although the contribution of agriculture to the economy has declined the value added per labor has been on the rise. Agriculture production unlike manufacturing and services are faced with more risks and uncertainties [2] specially since it is land based and highly contingent on the weather. Hence farmers are always faced with yield uncertainties due to pests and diseases, the weather and other calamities all beyond their control. The seasonality of

agricultural production result in the yield lag between supply and demand which impacts on the price too. Although there is a big demand for the commodity that could command a high market price at a certain point in time but since it is not the time of the year to grow the crop and also the gestation period takes time, farmers usually can not benefit from the demand and price. Moreover agricultural crops are bulky, highly perishable and with short shelf-life that before they reach the market much have been lost in weight and quality. Variability in the quality, size and shape is a contributing factor on market price of the products and this translates to variability in economic returns to farmers. All these factors just proves how vulnerable farm producers are to nature which make prices of the farm products and income of farmers highly fluctuating. But it is important also to note at this point that in advanced countries the uncertainties mentioned above are alleviated by the use of hydrophonics and greenhouses but these technologies are unaffordable / unavailable to ordinary farmers in developing countries.

## Factors affecting agricultural production

For decades the increase in agricultural productivity was brought about by expanding the acreage of land for farming, In developing countries some people do farming using the slash and burn method where they clear and burn forests and hillsides which are used as farmland. This has thus led to denudation of the mountains, destruction of the watershed and thus have caused inundation, flash floods and landslides and loss of lives and property to those living nearby. Likewise loss of biodiversity, meaning, plant and animal species just become extinct is another aftermath of slash and burn method of agriculture. But with increasing population there is now rapid

urbanization so many farmlands are transformed to residential areas and some are now converted to industrial estates. Scarcity of resources such as water and oil also affect quantity and quality of yield which are carried on into the price of the produce. Climate change is another area of concern since this cause either floods or drought. Global temperature has risen 0.7C in the last 100 years and will increase 2-3% in next 50 years [3] and thus will have an impact on agricultural production and there is the danger of plant and animal extinction.

Given the nature and characteristics of agricultural production as well as the challenges that the sector is facing, the following section presents how sustainable agriculture can be achieved and what science and technology (innovation in agriculture) can offer to this end.

## Sustainability defined

First the term sustainability will be defined in the context of agriculture. Many authors are unanimous in how they view sustainable agriculture which basically means that the food and feed crops are grown in such a way that our natural endowments / resources will be preserved, the environment conserved and protected, and at the same time agricultural production be done that would be profitable to the farmer in the long term and beneficial to society in general. In other words, sustainable agriculture has triple bottom line: ecological, economic and social aspects to achieve [4,5,6,7,8,9]. The Food and Agriculture Organization (FA0) [10] clearly gives the gist of sustainable agriculture as: " the management and conservation of the natural resource base, and the orientation of technological and institutional change in such a manner as to ensure the attainment and continued satisfaction of

human needs for present and future generations. Such development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically viable and socially acceptable." Further to this, FAO[11] pointed out that technology and institutions are likewise important for the management and conservation of resources which may include natural (land, water and plant diversity) and human resources as well as knowhow [12]. This supports the proposition that sustainable agriculture adopts the scientific approach that would result to increase production but not to the extent of compromising the natural endowments [13].

GTZ Sustainet made a summary of sustainability of agriculture from three perspectives : ecological, economic and social ; and the factors that describes the elements that comprise each dimension. This study however puts emphasis on the ecological and social aspects. A GTZ sponsored multi-institutional study done on sustainable agriculture in India has outlined the three facets of sustainable agriculture as mentioned above and the factors that are considered for their efficacy: ecological sustainability: soil fertility, water, biodiversity, pollution, landscape, climate; economic sustainability: export/domestic demand, credit; and social sustainability: local acceptance, indigenous knowledge, food security[9]. According to GTZ [9] ecologically, natural factor endowments like soil, water, plans, animals and the environment have all to be preserved and protected in the long term since not doing so would have a negative impact on agricultural production, On top of the ecological dimension there is the economics of agricultural production, meaning, it has to be economically viable. Otherwise farming would remain at subsistence level where farmers would produce crops only for their own use. But if there are big potential markets that can be tapped domestically

and globally, then agriculture can shift from the subsistence agriculture to commercialized farming of agricultural commodities as well as high valued added agriculture—based products. Credit is key though for farmers to be able to engage in commercialized farming and if the economic gains are assured, then financing will be easier to obtain [9].

Lastly agriculture also concerns the society not only in terms of food security but also involves the farmers in technology generation and dissemination. Cardenas [14] pointed out that there is now the paradigm shift from the traditional top-down flow of technology transfer meaning research results from research institutions are transferred to farmers in a unidirectional flow. Here farmer's participation is weak. This model according to Chambers [15] ignores the socio-cultural, and agro-ecological aspects of agricultural production. Rather he places the farmer at the heart of the technology transfer since he possess the indigenous knowledge and knows best what works and what not works. The farmer can contribute his own experiences in the research and extension of the technology. This is the participatory approach to technology transfer process, referred to as bi-directional flow. The transfer is successful if the recipient of the technology (farmer) can choose, acquire, adapt, produce and maintain the technology and if it is the appropriate technology transferred. Care has to be taken that the technology is suitable to the needs of the farmer hence it has to be technically and economically feasible, production and market wise, socially acceptable and environmentally friendly [16]. The adoption and diffusion of the alternative technology will be enhanced with the incentive of economic return; otherwise the technology will be dropped. Overall, the participatory concept of technology generation and extension can promote sustainable agriculture.

## Agriculture and the environment

In the 1992 Earth Summit held in Rio de Janeiro, Brazil, for the first time a consensus was reached that issues of agriculture and environment have to be pursued in parallel [3]. Delegates were unanimous in their communique that unless the environment is conserved and protected now and in the future, then agriculture will be adversely affected since farm production is natural endowment-based. How is this so? To grow agricultural produce the necessary inputs include land, water, labor, seeds and fertilizers and pesticides and weedicides on top of which is the favorable weather. Agricultural irrigation accounts for 70% of grounder withdrawals [17] so water shortage or drought can be detrimental to farming. Extensive use of fertilizers and chemicals and pesticides and weedicides that go with modern farming methods can be harmful to the health of the farmers and these chemicals pollute the rivers and streams through runoffs that would have repercussions to society in general. Intensive farming per area brought about by the constraint of available arable land has posed some environmental problems like soil degradation and exhaustion, deforestation, erosion and desertification and destruction of the watersheds. When we talk about environmental protection what comes first to our mind is to lessen carbon emissions and chemical wastes of the industrial sector that pollute the air and our waters. But little do we know that agriculture can have negative impacts on the environment because it is the main user of land and water, a major source of green house emissions (14% of greenhouse emissions in 2006,)[18] and the main cause of conversion of the natural ecosystem and loss of biodiversity. This is an irony since the environment has to be protected for agriculture to thrive now and in the future and yet the agriculture system seems to do the contra-

ry. Here then comes the issue of sustainability more specifically the relationship between technology and agriculture and environment sustainability. In this context agriculture should be economically viable, ecologically sound and be done with social responsibility in mind, thinking of the well being and human welfare, of producers and consumers, all together would comprise sustainability of agriculture.

## Technology innovation and sustainable agriculture

Always the issue at stake is how technological innovation can be used for sustainable agriculture. A famous agricultural economist, Tweeten [19], said that, " Science and technology in agriculture can be used as a solution to the problem rather than causing the problem. Continuous R&D (innovation) in agriculture is important since food is linked to agriculture which is linked to human survival [18]. For another the demand for food keeps growing and insects and plants keep adapting so agriculture R&D is never done, according to Prof Robert Worth and Baja Bakr [20] and the director of the International Rice Institute (IRRI) states that we should stay ahead of the fast evolving pests and diseases and the rapidly changing environment to ensure global food security [20]. Whereas till the 1970's biotechnology was mainly used in food processing and agro-industries, from the 1970's on, with developments in tissue culture and genomics, biotechnology became popularly used in agriculture as well.

Actually throughout the years technological innovation such plant breeding, tissue culture and molecular genetics have been in practice. The former involves horizontal gene transfer across plants of the same species that carry certain traits like disease, pest and stress resistance or high yielding varie-

ties. This agricultural biotechnology will lead to the development of disease, insect, nematode and insect resistant varieties of crops as well as enhance yield by developing crops resistant to salinity, drought and flooding, delayed ripening and longer shelf life. IRRI has developed a rice that can survive 17 days submerged in water. Rice grows in paddies but if the rice plant is completely submerged in water, they die 3-4 days later. The Institute also developed an aerobic rice crops that can grow in areas where there is drought or little water and yet yield 3-6 tons per ha. Rice resistant to salinity so farmers living near the seas can still grow rice is now being researched on. Knowing the fact that 85 percent of water use is for agriculture and 40 per cent of the cost of production is spent on irrigation, poor water management can have detrimental impact on the plant and land. This calls for more efficient irrigation system and better technology. In some areas in the world people do not have enough food to eat because of the harsh conditions, dry land and soil exhaustion. Scientist are now developing rice and wheat varieties resistant to drought. In Africa, hybrids of rice which combine the high yielding variety of Asian rice and the local African varieties that grow in dry weather and are resistant to diseases that could be cultivated in rain fed farms in Africa are at the initial stage of application. Tokyo University and Nagoya University scientists have come out with a rice genus that would withstand strong winds with thicker stalks by crossing the Indica and Koshihikari genes (21). Also technology has made possible the development of vitamin A enriched rice (golden rice) which is still waiting approval. One bowl of the golden rice gives the same nutrients as one bowl of spinach. Biotechnology was used to improve quality and improved shelf life that would delay ripening as in tomato and papayas. Japanese scientists are developing rice which contain less protein glutelin that causes rice to loose

its taste and rice that has the power to reduce cholesterol but also foods that would increase their practicality. The Naro Institute of Vegetable and Tea Science with the use of genomics have developed shorter leeks to make transport and storage less troublesome and chestnuts that are easy to peel, crop traits enhancement that would appeal to consumers (21).

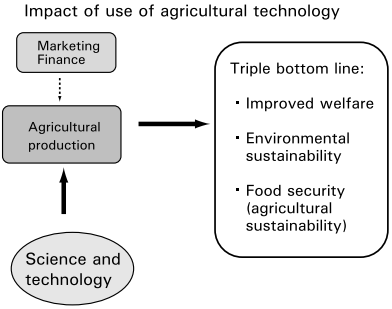
## Sustainable and environment conducive agricultural production

The good traits of crops of the same genus are combined to develop high yielding, insect and pest and stress (drought, flooding, salinity) resistance will lead to increased yield per acre lessening the impact of limited land for farming. This is also necessitates less use of chemicals that are harmful to farmers and the environment. Natural Environment Research Council of the UK [22] indicated that biotechnology such as the vitamin enriched rice, protein enhance potato, low flatulence beans or seedless watermelon etc. can enhance the quality and nutritional benefits of the crop. In other words, agricultural technology can lead to yield / income enhancement per ha, yield stability and water and energy conservation not to mention that it can reduce risk to humans and the environment and improve crop quality and nutritional value too.

When we talk about technology, what comes to our mind is genetic improvement but there exist also other techniques such as better crop management system like zero tillage and crop rotation which are ecological method of farming. Zero tillage or conservation tillage tries to keep to the minimum tillage and maintain crop residues as ground over after the end of the crop season [3]. This saves on labor, conserves the soil, keeps the moisture and

reduces greenhouse emissions. In India rice-wheat crop rotation is used. After the rice harvest wheat is grown, allowing the wheat to germinate using moisture remaining in the filed. Wheat yield will improve cutting cost on water and chemicals and also maintain a better soil structure. Intensive agriculture also leads to depletion of soil nutrients which have to be replaced using chemicals. There is a crop rotation system using legumes to improve soil fertility which is input saving and resource conserving approach to farming. In Australia, cereal production (what, oatmeal, corn) is rotated with legumes (peas, beans, peanuts) that would introduce biologically fixing nitrogen in the soil instead of applying fertilizers [3].

The relationship between agricultural technology and environmental sustainability can be explained. R&D in agriculture can lead to the development of crop varieties that will use less pesticides and fertilizers, conserve water and the soil and at the same time protect biodiversity which at the end will protect and conserve the environment. Agricultural technology and sustainability mean R&D in agriculture will result to yield growth through genetic improvements in crop varieties in a given land area, better crop management practices, and better post-harvest practice. This will preserve our natural resources that are important for agriculture to survive for generations.



The figure above gives us a rough idea of how agricultural technology given that credit / funding is available and market exists (part of the economic sustainability aspect) can be useful to achieve the three objectives that the use of biotechnology can achieve. One is to provide enough food for every one and second to conduct farming profitably that would conserve and protect our pristine environment. These two factors would led to improvement and betterment of the lives of the farmers and people in general but the third as important objective is food security which is basically how to protect and enhance the welfare of the people by making sure that the food offered to them and their families are safe.

## Agricultural technology and welfare

It is hoped that the use of technology in agriculture will improve productivity and provide better income for farmers and in a way alleviate poverty at the same time improve nutrition and render less risk to the health of producers and consumers alike. How about the other end of the supply chain, the consumers. In many developing countries price is still the determining factor in the purchase of food. And often there is asymmetric information on food safety, if ever this information even ever exists. Unlike in developed countries where consumers are more demanding and knowledgeable and thus can make the rational choice of whether to buy organic or biotech food given the strong and well-organized supply chain which keeps consumers informed of the nature / contents of the food they eat as part of their social responsibility. Often regulations are in place to assure the safety of the consumers but the situation in developing countries is quite the different. Hence it is important for domestic and international regulations to protect

consumer but giving them the freedom of choice. Regulators and government officials who will be involved the development, implementation of food regulations should have the technical capacity to do so and they have to be trained on this. Hence the importance of international regulations that would bind, attune and govern national policies on food safety and domestic policies and regulations need to be in harmony with international regulations. Developing nations who are still trying to strengthen their national regulations can be guided and bounded by these international framework and institutions such as the Cartena Biosafety Protocol, FAO / WHO Codex Alimentarius, WTP SPS agreements and International Plant Protection convention.

Labeling may add costs to the firm that will be passed on to the consumer. Due to budget constraints, or no other food alternative or a lack of knowledge of the food labels consumers in developing countries may not always take notice of the food labels. Nevertheless, the public / consumers can be provided all the information on ingredients in food products and let them make the rational choice. Education of producers, processors, retailers and consumers alike of the potential benefits and risk of biotech crops is important and let them make informed decisions. This could be done using the extension arms of the national and local government in cooperation with community associations in the countryside as well as NGOs. In developing countries there is still the need for capacity building of local officials and researchers that would be involved the development and implementation of local food safety programs and measures. Hence there could be training in areas such food safety, review and updating of food regulations, etc. On the regional perspective, nations in Asia should work together and coordinate their efforts to make sure that the foods that are being developed are safe before they are disseminated and commercialized given the fact that these

countries more or less grow similar crops and are faced with constraints such as human, financial and institutional capital. Information (data base) sharing is very important as far as health risk assessment and analysis are concerned to avoid duplication and thus save on the cost. Lastly continuous research and safety assessment of potential risk of the food we eat should be done, maybe on a regional basis so that information and data base sharing system can be formed.

Given the above the consumers will make their rational decision on the choice of food and this will ripple back to the value chain. Consumers are a strong driving force behind the food system. The growth and economic sustainability of agriculture in a great way is at the hands of the consumers.

## Concluding note:

The 21 century is marked with breakthroughs in technological knowhow that was unimaginable before. These recent developments have also changed how technology used in agriculture has evolved. There are various forms of agricultural biotechnology that promotes advanced technology and eco—friendly based agriculture that would increase the economic returns to farmers but can also make farming done in a sustainable way and at the same time conserves the environment. Agriculture is natural resource—based which are on contingent on how we protect and conserve are environment. If we destroy our environment, then agriculture will suffer. If agriculture suffers then people, specially the poor, will not have enough food on their plates. Hence technology can be used to have a sustainable and environmentally sound agriculture with safety of society a vital concern in accordance to the national and international framework and regulations.

**References**:


1. Malthus T.R. (1798) An Essay on the Principle of Population. Chapter 1, p.13 in Oxford World's Classics reprint.
2. Sporleder T.L. and Michael A. Boland (2011) Exclusivity of Agrifood Supply Chain: Seven Fundamental Economic Characteristics, International Food and Agribusiness Management Review, Vol.14, Issue 5.
3. World Bank (2008) World Bank Development Report, Agriculture for Development.
4. Sakai, Naoki (2009) The Scientific Basis and Present Status of Sustainable Agriculture, Journal of Developments in Sustainable Agriculture 4:7-10
5. Ikerd, John (1990) Sustainability's Promise, Journal of Soil and Water Conservation) Jan-Feb. 45(1), p.4
6. Francis C.A., C.B. Flora and L.D. King (eds.)(1990) Agriculture—An Overview," in Sustainable Agriculture in Temperate Zones, New York: Wiley.
7. O'Connell, Paul F. (1992) "Sustainable Agriculture, a Valid Alternative," Outlook on Agriculture, 21(1).
8. Gliessman, Stephen R. (1998) "An Ecological Definition of Sustainable Agriculture," Principles of Agroecology and Sustainability. Available at Agroecology Home Website: http://agroecology.org/Principles_Def.html (6/9/08)]
9. GTZ Germany Sustainet (2006) Sustainable Agriculture: A Pathway our of Poverty for India' Rural Poor
10. FAO (1995) Sustainable Agriculture and Rural Development, in FAO Trainer's Manual, Vol. 1,"Sustainability Issues in Agriculture and Rural Development Policies, http://www.fao.org/wssd/sard/faodefin_en.htm. Accessed Feb. 3, 2012.
11. FAO (1994) Development and Education Exchange Papers (DEEP): Sustainable Agriculture and Rural Development: Part 1: Latin America and Asia, Rome, p. 5.
12. Reijintjes, et al, (1992) USDA Natural Resource Conservation Service (NRCS) General Manual (180-GM, Part 407). Available at USDA Website: http://www.info.usda.gov/default.aspx?l=176 Select Title 180; Part 407—Sustainable Agriculture; Subpart A—General. (10/20/09)]
13. Union of Concerned Scientists (1999) Sustainable Agriculture—A New Vision (1999). Available at UCS Website: http://www.ucsusa.org/food_and environment/sustainable_food/questions-about-sustainable-agriculture.html (8/23/07)]

14. Cardenas, Virginia (1995) Extension Paradigm Shift for Sustainable Development, UPLB Association Professional Chair, Lecture, UPLN.
15. Chambers, R (1993) Methods for Analysis by Farmers : The Professional Challenge. Journal for Farming systems Research Extension, Vol.4 No.1.
16. FAO (1996) SD Dimensions: Technology Assessment and Transfer for Sustainable Agriculture and Rural development in the Asia Pacific Region.
17. FAO, Crops and Drops, Land and Water Development Division, FAO corporate division repository, FAO Rome(2002), http://www.fao.org/docrep/005/y3918e/y3918e00.htm Accessed August 12, 2012.
18. Intergovernmental Panel on Climate Change (IPPC) 2007, Mitigation, Chapter 8, IPPC working group, 2007.
19. Tweeten, Luther (2003) Terrorism, Radicalism and Populism in Agriculture, Iowa State Press.
20. J. Leach (2008) Asahi Newspaper, May 19.
21. Kusashio, T. (2012) Crop Improvements Help Make Common Foods More Practical, Nikkei Weekly, 20, Oct. 15.
22. Natural Environment Research Council of the UK (2012)http://www.nerc.ac.uk/research/issues/geneticmodification/what.asp Accessed March 27, 2012.