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Impact of Global Changes on Food Security and Climate Smart Solutions

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地球環境問題と食の安全性の関係及びその賢明な解決策に関する一考察

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Summary

Global food security is one of the biggest challenges humanity is facing right now (intertwined with water security because there is no food security without water security). Agricultural production is a key to achieving food security and depends on biophysical factors (such as availability of land, water; climate change; land degradation to name a few), economic conditions (affordability of farmers to buy seeds, water) and national food policies. However, the risks posed by climate change and seasonal variability as it impacts agriculture and crops are a major policy concern in achieving food security. The paper discusses the impact of global changes such as population growth, availability of arable lands, water resources, climate change (change in temperature and precipitation), food availability, accessibility and loss, diet diversification bio-fuels and changing patterns of crops due to globalization on food security. The paper then explores some solutions to achieving food security in the face of factors such as climate variability and discusses some climate smart approaches to agriculture, livestock and aquaculture management. In addition to the technical solutions, the paper also explores some policy options for achieving food security. One of such examples is a case study from Japan based on payment for ecosystem services. The final section looks at the impact of climate change on rice production in Laos and the Philippines and how some of the people are adapting to changing climate. Most of the paper relies heavily on secondary sources but the case study of Japan is based on the research by one of the authors. This paper can be used as a reference guide and references can be further explored to get detailed information.

Keywords: Food security, water, population, climate change, climate smart approaches

要　旨

食糧安全保障の問題は、地球規模での大きな問題のひとつである。この問題は、食糧生産と水との関連性というに観点において、水の確保、水の安全性の問題とも深く関係している。農業生産は、食の安全性の問題を解決する際の重要な糸口のひとつであり、生物物理学的な要因（土地や水の確保、気候変動、土壌劣化など）、経済事情（種の購水や水道料金の支払いという農家の経済的負担など）、食糧需給に関する国際的な法律のあり方に大きく左右される。しかし、気候変動や農業やその収量に大きな影響を与える季節的な変化から、農業には様々なリスクがある。農産物の生産は、食の安全性を解決、確立するための主要な政策として位置づけることができる。本稿では、人口の増加、耕地の確保、水資源の確保、気候変動（気温や降水量の変化）、食糧の需給、利便性、廃棄、飼料の多様化やさまざまなバイオ燃料の流通、農産物種の豊富化などといった地球規模での変化がもたらす食の安全のグローバリゼーションについて考察する。

本稿では、気候変動などの要因にも直面している食の安全性をどのように確保するかという問いに対する解決法について論考を進め、農業、家畜の管理に対する賢明な対処法について議論する。加えて、技術的な解決方法についても言及し、食の安全性を確立するためのいくつかの政策的な選択肢を提示したい。生態系サービスに対する支払いといった観点にもとづく日本での事例、米の生産に対する気候変動の影響について考察を深め、実際に米生産に携わる農家がどのようにして気候変動に対応（順応）してきているかについてのラオスとフィリピンの事例取り上げる。

なお、本稿の事例の大部分は文献調査に基づくものであるが、日本の事例に関しては執筆者のひとりの現地調査によるものである。本稿は、ある種の文献ガイドとしての利用も可能であり、執筆者たちはそれを期待している。

キーワード：食の安全性、水資源、人口増加、気候変動、賢明な解決策

Introduction: What is food security?

Food security is a complex socio-political concept which is more than just producing and supplying food. It is a relationship between humans and nature that incorporates values and perceptions of food in the security of society (Fullbrook, 2010). **Food security exists** "when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life" (World Food Summit, 1996).

Global food security is one of the major challenges humanity is facing right now (intertwined with water security because there is no food security without water security). Even the UN Millennium Development Goals have the very first MDG calling for member countries "to reduce the proportion of the world's population that suffers from hunger by half between 1990 and 2015" (UN, 2000). "Developing regions as a whole have registered significant progress towards the MDG 1 hunger target. If the average annual decline of the past 21 years continues to 2015, the prevalence of undernourishment will reach a level close to the target. Meeting it would require considerable and immediate additional efforts" (FAO, IFAD and WFP., 2013, pp. Kindle Locations 280-282). Agricultural production is a key to achieving food security and depends on biophysical factors (such as availability of land, water; climate change; land degradation to name a few), economic conditions (affordability of farmers to buy seeds, water and ability of consumers to buy food at reasonable prices) and national food policies (Sundstrom, 2014).

Food security in developing countries—like Laos, PDR, Philippines, Nepal and India—with a large rural agricultural base, where hundreds of millions of people are currently struggling to subsist, will face more frequent droughts, floods or heat waves that can devastate crops and threaten their livelihoods. Hence, the risks posed by climate change and seasonal variability as it impacts agriculture and crops are a major policy concern. The livelihood of farmers may suffer due to production losses associated with water stress related to climate change and destruction of productive assets. The increasing weather variability may require adjustments in cropping patterns in order to lessen possible adverse impacts. Given some level of uncertainty in climate change projections, adaptation actions require even more conscientious planning. With the limited capacity of particularly small-scale farmers, appropriate interventions may be necessary to enhance their means of coping with such issues. The impacts of climate change in agriculture, however, are expected to be multifaceted because of heterogeneity in farming systems across countries and agro-ecological zones (ADB-IFPRI, 2009).

Agriculture is by far the largest consumer of freshwater. Globally, about 70% of freshwater (and up to 80% in some parts of California with a subsidy of up to 85% (The Economist, 2013)), is used in irrigated farming, and far greater volumes of water are used in rain-fed agriculture. With changing climate, changes in temperatures are predicted. Although average temperatures are predicted to increase more dramatically in the northern hemisphere, the changes in temperature-dependent agriculture will be felt more significantly in developing regions because of their heavy reliance on small-scale farming, dependence on rainfed agriculture, a fragile infrastructure and limited capacity to respond to emergencies. Many African communities will be at risk, particularly subsistence farmers with low incomes in sub-Saharan Africa. This will essentially impact the income of these small farmers, as increased droughts may exacerbate poverty levels and increase the vulnerability of these people. The United Nations scientists warned in 2005 that one in six countries are facing food shortages because of severe droughts that could become semi-permanent. National communications report that climate change will cause a general decline in many subsistence crops, for example sorghum in Sudan, Ethiopia, Eritrea and Zambia; maize in Ghana; millet in Sudan; and groundnuts in Gambia. Africa already accounts for a large proportion of the total additional people at risk of hunger as a result of climate change; by the 2080s it may account for the majority. Also, changing temperature, precipitation, humidity, rainfall and extreme weather related incidents will make food security more complex. For example, studies in countries such as Mali and Nepal suggest that by 2050, 72% of the population could face serious food shortages (Accenture, 2011, Grover, 2013).

In spite of the fact that we are facing food shortages, more attention is given to oil and oil production and hardly any attention is given to water. Attention is now, at last, shifting to water and water security. Food is also necessary for life and is a fuel needed for human survival but not sufficient attention is being given to food security (it hardly ever makes it to the top priority of any nation). Putting food security on the national agenda will contribute to comprehensive sustainable security, providing livelihood, maintain ecosystems and the well-being of citizens and society. Food security came more into limelight in 2008 when the sharp increase in food prices led to riots, strikes, more hunger and a rise in poverty and malnutrition in developing countries. At the same time some third world countries also reduced or suspended export of rice leading to extreme steps taken by countries such as Kuwait, Saudi Arabia and South Korea of buying or leasing lands in South East Asia and Africa to produce food for their populations (Fullbrook, 2010). Food insecurity is increasing mainly because of worsening stresses in supply and demand of food commodities. Although there is an annual increase of annual yield of 1.3%, demand growth outstrips this rise (Fullbrook, 2010). Some lessons from history also suggest that food security should be brought into the national security agenda: for example, in AD 51 it was the hungry crowds that threatened Roman Emperor Claudius and the French Revolution in 1789 is also attributed to bread riots (Behnassi, 2013).

This paper will look at the components of food security followed by "drivers of change impacting food security" and the impact of these drivers (such as climate change) on food security in some countries and will suggest some technical and policy related recommendations/solutions to deal with food insecurity. The paper is mainly based on information and analysis of secondary data and reports.

Components of food security

The last section looked at food security in general, in this section we will briefly look at the components of food security (see Table 1):

Table 1: COMPONENTS OF A FOOD SYSTEM

Determinant	Likely effects of climate change
Availability of food	Decreases in production due to a variety of changes: More frequent and intense extreme weather events Changes in temperature and rainfall Declines in the availability of arable land and insufficient water for irrigation Unavailability or lack of access to resistant varieties of seed and breeds Increases in pest infestations and the incidence of diseases
Access to food	Damage to infrastructure and loss of livelihood assets Loss of income and employment opportunities
Utilization of food	Increased food safety hazards associated with the increase in pest infestations as well as animal and human diseases
Stability of food supply	Food price fluctuations, changes in the supply chain infrastructure, and a higher dependency on imports and food aid

Source: FAO (2008); Gregory, et al. (2005); Parry et al. (2005); Schmidhuber; & Tubiello (2007)

In the debate on food security it is frequently the case that some important elements are missed and need to be included for achieving food security in broader sense, for example, (Wahlqvist, 2012):

1. There is a need to broaden the theme of food security to go beyond just survival, well-being and poverty eradication to include issues of societal stability and traditional national security.
2. The lens of food security should be broadened to a more long term perspective to include threats from climate change, population growth, urbanization etc. (as discussed in drivers of change section below)
3. Food security needs a more strategic and integrated approach than just technological fixing (maybe the focus should be on climate compatible development)
4. Market based approaches might not be a solution for all regions
5. The food security definition should be expanded from food supply and quantity to also include food safety, nutrition, health, developmental impact on children and entitlements.

In order to broaden the lenses of food security/insecurity issues, the next section discusses drivers of change impacting food security.

Drivers of change impacting food security together with some of their impacts:

Food security is affected by a few different factors such as population growth, availability of arable lands, water resources, climate change and food availability, accessibility and loss (Premanandh, 2011), soil pollution, pests and diseases in animals and plants (Sundstrom, 2014), social and economic drivers (Behnassi, 2013), diet diversification and trade liberalization (Rosegrant, 2010).

Influence of population growth (Explosion):

The global population in 2010 reached 6.9 billion. Most of this growth in people occurred in developing countries (exacerbating poverty and increasing pressure on limited resources and environment) while the developed countries continued to experience low birth rates and aging populations (creating health and financial security issues especially for elderly). By 2050 the global population is expected to be between 8 and 10.4 billion. The African population will likely double to 2.1 billion while Asia is expected to have a smaller proportional increase than Africa, the Asian contribution would still remain largest by an addition of 1.3 billion people by 2050. Since both these areas are already facing issues related to water scarcity—any increase in population will add to the existing problems. This continuing increase in population (and proportionate increase in consumption) is one of the major threats to global food security (Premanandh, 2011; Heath, 2014).

Arable land:

Although there are about 14 billion hectares of land, only 3 billion is arable and the available arable land is dwindling. With the increase in population and industrial agriculture, industries etc. the amount of arable land per person has decreased. In 1959, 12 acres of arable land per person was available as compared to only 6 acres per person in 2006 (Premanandh, 2011). According to current estimates about 15% of the global land area is seriously affected by land degradation while about 46% is moderately and 38% is lightly affected (Sundstrom, 2014). Most of this decline (up to 55%) has been in developing nations (where there is maximum population growth, as discussed above). The problem will be further aggravated by the fact that half of this arable land will become unusable by 2050 because of degradation (i. e. soil erosion, desertification) and the rate of degradation will be two to six times higher in Asia, Africa and Latin America than in North America and Europe. Land degradation is not only a threat to food production but also to rural livelihoods in developing countries. Since there is competing demand for land for wood, bioenergy, feed (among other things such as housing, industries) the land available for food production is further expected to decrease. The concern is that this will lead to deforestation (leading to other environmental problems) and still there will be lack of availability of land for increased demand in food production (Premanandh, 2011). Policies such as payment for ecosystem services and subsidies influence land degradation and can be used to moderate the rates of degradation (Sundstrom, 2014).

Soil contamination:

Good and healthy soil is important for supporting plant growth by providing nutrients and also regulating nutrients (e.g. N, K, Ca, Mg, S and P), water, carbon and gaseous cycles (Food and Agrilculture Organization of the United Nations, 2013). However, chemical and radioactive pollution of soil from industrial accidents or other sources contaminate soil and crops grown on the contaminated soil and raise questions about food safety and diseases caused by such crops. Unfortunately not much literature exists that point out linkages between acute pollution and losses in agricultural production. There is, however, one exception—metal pollution. Some literature suggests linkages between losses in agricultural production and heavy metal contamination and surface ozone exposure. Links have been established between concentration of cadmium and photosynthetic capability of some plants and also decrease in yield of some crops (for example rice in Iran). In addition to chemicals and metals microbes also pose a threat to an agricultural environment and may render agricultural activity impossible. With the literature available so far, microbial contamination can be seen more as an issue for food safety than food security (Sundstrom, 2014).

Water resources:

Although when we look at the globe (planet earth) most of it (70%) looks blue, however the amount of water available for human consumption is limited. Water is usually considered a renewable resource (hydrological cycle recycles water between the earth and the atmosphere) but since industrialization, large scale agriculture, and increase in water consumption we are withdrawing water at a higher rate than it can recycle itself. With growing demand and competing needs, the availability of water for agriculture is decreasing. Global water distribution is uneven and as discussed in a UNEP report more than 3 billion people will be in the water scarce category (1700 m^3 per capita) by 2025. It is anticipated that by 2050, agricultural water demand will increase 1.3 fold, industrial demand is projected to increase 1.5 fold and domestic consumption will increase by 1.5 fold—at the same time water quality will decrease due to increased use of chemicals and quantity in water cycle will also be affected. In some places ground water is also drawn out at a faster rate than it is being recharged while ground water contamination is also a wide spread problem. One of the major concerns regarding groundwater is that water extraction is occurring at a much higher rate than recharge, thereby lowering the groundwater table. Other threats to groundwater use include waterlogging and salinization. Since agriculture (and food supply) is directly dependent on water availability, this is one of the major threats for food security

(Premanandh, 2011; Rosegrant, 2010).

Food security is very closely linked to water security. Water scarcity affects cereal production —for example, "for the base year of 1995 grain harvests in developing countries fell short by 90 million mt as a result of water shortages. By 2025, the production shortfall is expected to grow to 296 million mt under business-as-usual conditions and to a much higher 440 million mt if investments in agricultural research and water infrastructure slow even more" (Rosegrant, 2010, p. 19). Both water and food scarcity lead to malnutrition and related health problems.

The effort should be to increase crop production per drop of available water (see more in the solutions section).

Climate change:

Impact of climate change on agriculture: Agriculture is dependent on local average temperature and rain-fall, this impacts the type of crop that can be grown, sowing and reaping times as well. With changing climate (rise in average temperatures, change in amount of precipitation and also change in the timings of rainfall season, melting glaciers) there will be an impact on water availability, rising temperatures lead to increased evapotranspiration rates lowering water availability further and also leads to heat stress in plants decreasing the overall productivity. It is estimated that each per degree (C) rise in temperature would lead to about 5-15% decrease in crop yield. Impact on crop yield will be very regional—for example in Asia rice yield production might increase (Premanandh, 2011). According to (Premanandh, 2011), "Thus, considering the current growing regions unchanged, average yields of major crops such as corn, soybean and cotton are predicted to decline by up to 46% before the end of the century". Studies have shown that there is a strong negative effect from climate change especially in the tropics. Results from the simulations that have used the values for realistic nitrogen availability show that there will be severe impacts of climate change in both tropical as well as temperate zones (Lifson, 2013). In northern latitudes or higher latitudes an increase in temperature will prolong cultivation season and lead to higher yields (Eckersten, 2011). Heat stress during pollination periods will increase the vulnerability of some commodity crops to pests and diseases. Evidence also points out to the fact that increase in atmospheric CO_2 stimulates both photosynthesis and mass production for some species, however, some studies have also suggested that increase in temperatures causes negative impact on the same processes—thus the combined effect of both is decreased photosynthesis as well as decrease in production. In addition to temperature change extreme climate events such as increasing intensity and frequency of floods and droughts, heat waves will lead to more erosion, leakage of soil minerals, landslides, contamination of soil leading to loss of arable land for agriculture. These factors might also change the type and number of pathogens (and pathogen transmission dynamics) and increase the presence of insects and pests impacting crop yield (Sundstrom, 2014).

Impact of climate change on animal production: Changes in temperature will also have an impact on animal production since the rise in temperatures increases the risk of vulnerability to diseases (Premanandh, 2011). A rise in temperature can also cause heat stress leading to reduced fertility, feed intake and immunological responses thus increasing mortality and increasing metabolic diseases in animal production. Increased temperatures would require supplemental cooling for production of pigs, chickens and even for dairy cows. Another factor impacting animal production will be extended periods of droughts which will cause shortages of feed and drinking water (Sundstrom, 2014). The fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) has discussed that global climate change will have devastating impact on food security, and will disproportionately impact people on social and economic margins (Dixit, 2013). The IPCC fifth assessment report links the impact of climate events to droughts and food shortages "The impacts from these zonal South Pacific Convergence Zones events are much more severe than those from moderate El Niño events, and can induce massive droughts and food shortages (IPCC, 2013, p. 1964)."

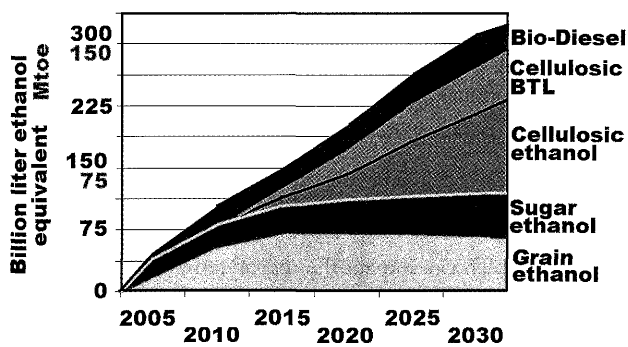
Impact of climate change on fisheries: Fisheries also play an important role in both—the economy of countries (and income for farmers) as well as providing food security. Studies have shown that currently fish contributes about 20% of animal protein in the diets which is expected to increase to 50% in the world's poorest areas and up to 90% in the small island developing countries in the Indian and Pacific Oceans. However, climate change and the environmental changes associated with it (i.e. higher water temperatures, storm surges, increase in ocean acidification) are impacting marine ecosystem and fisheries. For example, El Nino is impacting the distribution patterns of migratory fishes, which can impact the reproduction and growth of oceanic fish species (Heath, 2014).

Some researchers see Aquaculture as a competitor for water use for agriculture. Aquaculture, the cultivation and marketing of aquatic plants and animals in a controlled or semi-controlled environment, is one of the fastest growing sector of animal production. However, both land based and water based aquaculture depend on water quality and water quantity—it adds to the list of other competitors for the limited amount of water available. In 2002, of the total fish production (128.8 million metric tons), 71% was captured fisheries and only 29% was from aquaculture, however the projections show that aquaculture share would increase to about 68% of the total increase in fish production (Rosegrant, 2010). The authors of this paper have not discussed this as a threat to food security, since fish (sea food) is part of diversification of food basket and a solution towards food security. As discussed by Rosegrant (2010), aquaculture not only plays an important role in meeting food security and nutritional requirements (protein) of poor people but also contributes towards the economies of developing countries (by helping poor fish farmers).

Other factors (biofuels and cash crops):

The use of corn and other food feedstock could affect worldwide food supply and availability in a way that if the farmers choose to grow crops for production of bio-fuel it will impact food supply and this will then increase competition for limited resources (water and land) and also impact prices of food (because of limited supply and increased demand). As discussed by some authors, the impact of the biofuel production is related to three other parameters: climate change, population development and energy demand and satisfaction (Spiess, n.d.). For example, "It is assumed that transport energy demand develops as projected by IEA in its WEO 2008 Scenario assuming that mandatory and voluntary or indicative targets for biofuels-use (as announced by major OECD and Non-OECD countries) will be implemented by 2020. This will result in about twice the biofuels consumption compared to 2008" (Spiess, n.d., p. 7). However, it is also expected that the first generation fuel (produced from grains, sugar-cane and oil seeds) will be replaced by second generation fuels (based on cellulosic material and none-food feedstock). Bio-diesel might move from oil seeds to Palm-Oil and Jatropha (see Figure 1):

Figure 1: World Biofuel Production by Type



(Source: (Spiess, n.d))

"The target of achieving a 10% biofuels share in transport fuel at the global level can be met but this causes about a 15% increase in the number of people at risk of hunger (i.e., and increase 140-150 million people at risk of hunger as compared to 2008 numbers). In particular the poor urban population, subsistence farmers and the landless in developing countries will bear the brunt. ... To avoid negative impacts of biofuels on food security, any use of first generation biofuels would need to be preceded by concerted research efforts to increase agricultural productivity. The foremost priority is to ensure that future food demand is met and only then any surplus production would be available for biofuels (Fischer, 2009)."

The debate between growing cash crops (and earning money to buy food) vs growing crops for food (and local consumption) has been there for a while.

Pests and diseases in animals and pests:

Trans-boundary animal diseases are at times highly contagious and easily transmitted across boundaries threatening the economic health of livestock, livelihood of farmers and food security. For example pathogenic avian influenza in East Asia (2003) and foot-and-mouth diseases in Great Britain (2001) led to huge financial losses (about 3.1 billion GBP from just foot-and-mouth incidence in 2001) and posed a threat to livestock production and food security. It is difficult to predict how the plant diseases will spread and the magnitude of the spread mainly because it depends on environmental conditions as well as plant-pathogen interactions. But the risk of spread of plant diseases has increased in large fields with uniform crop cultivation, especially where there is high planting density and increased use of fertilizers (Sundstrom, 2014).

Food availability and accessibility:

Food availability and accessibility include two concepts: availability, if there is enough quantity of necessary food types available for individuals, communities, and nations while accessibility refers to the purchasing power of individuals (and is related to individual incomes). Rural communities have less purchasing power and thus face more food insecurity. In addition to food availability and accessibility, it is important that the food available/accessible also meets the local daily dietary requirements. Food demand has increased and crop yield has decreased over a period of time brining global food reserves to their lowest level in 35 years in 2007. Food price increases in 2007-08 raised the food prices to their highest levels since 1970 leading to an increase in global poverty from 100 million to 200 million people. Although, prices have come down since late 2008, still a large number of people do not have enough purchasing power to provide for a healthy diet leading to malnutrition and poverty (Premanandh, 2011). Harvest failure, droughts, food import issues etc. contribute to some physical food shortages but the main problem of famine (food shortage) is the social distribution of the available food in the society and social system the society has. As noted by Sen, "If one person in eight starves regularly in the world, this is... the result of his inability to establish entitlement to enough food; the question of the physical availability of the food is not directly involved" (Sen, 1982: 8). One of the problems is that when prices rise consumers tend to move from more expensive and more nutritious food to less expensive but less nutritious food items leading to malnutrition and associated issues of micronutrient deficiencies (FAO, IFAD and WFP, 2013). Global recession is impacting employability leading to further declines in purchasing power of poor people who cannot afford healthy diet (Premanandh, 2011).

Another issue is that agriculture is main livelihood of the smallholder farmers (about 450 million) and most of them are in Asia. Most of the natural disasters impact these smallholder farmers threating their livelihoods. The same smallholder farmers are also impacted by increasing prices of seeds, fertilizers and diesel. These farmers have to invest more money but they do not benefit from higher output prices (Heath, 2014).

Food loss:

Food loss occurs at several places in the food supply chain starting from crop loss due to rodents, pests, diseases to lack of effective harvesting to lack of storage facilities at farm (or cold storage for vegetables and fruits), to lack of transportation facilities to market, food wastage at household levels (nearly one-third of food purchased is wasted). Although it is difficult to estimate food losses along the food supply chain, it is estimated that between 20 to 40% of food loss occurs (non-perishable items such as grains account for 15% loss postharvest while perishable items such as fruits and vegetables account for about 33% losses). The major contributor to food losses in developing countries is the lack of adequate infrastructure—for example about 30% of vegetable production in India is wasted because of lack of cold storage facilities (Premanandh, 2011; Behnassi, 2013).

Socio-economic drivers:

Some social drivers such as urbanization, demographic changes between urban and rural areas, issues of land tenure and ownership, local governance and institutional changes, international securities, changing consumption patterns (as discussed above there is an increase in demand for meat than cereals), what consumers want and prefer (their habits and practices) affect the demand for and consumption of different foods (Behnassi, 2013).

On the other hand economic factors include things such as land tenure, food markets and volatility of food prices, trade issues such as supply and distribution of food, regulations, liberalization and globalization of markets. This also impacts the accessibility of goods (Behnassi, 2013).

Diet diversification:

With the change in economic conditions, globalization and development food basket has changed in different regions. Dietary patterns have changed with the change in disposable income and urbanization which has seen an increase in demand for wheat and rice (a shift from maize and other coarse grains) and increased consumption of meat, fruits and vegetables. For example, global demand for cereal has been projected to increase annually by only 1.3% between 1995 and 2025 as compared to 2.2% annual increase in 1965 to 1995. Essentially this means an increase by 828 million metric tons of cereals by 2025 and most of this (712 million metric ton) is expected to be in developing countries. On the other hand, meat consumption is increasing rapidly—projected demand for meat by 2025 is expected to increase by 138 million metric tons globally. It is interesting to note that about 86% of this increase is in developing countries, where meat demand would more than double. This increase in meat consumption would also mean increase in demand for animal feed (Rosegrant, 2010).

Change in climate and availability of water resources is impacting what can be grown, what is available and how much is the yield but changing diets will add another challenge on access to what people want to eat (which can be different from what is traditionally grown locally).

Ensuring global food security does not mean that we need to standardize a global common diet and eating pattern for everyone but we need a more holistic approach to make eating patterns more suitable and healthy. Some of the actions needed to reduce losses and waste along the whole chain (Behnassi, 2013). There also needs to be a change or a paradigm shift where contribution of agriculture should shift from just feeding people to improving household nutrition (McDermott, 2013). Essentially this means that we should go beyond just meeting food security to "nutritional security" which according to the World Bank (2013) is defined as "the ongoing access to the basic elements of good nutrition, i.e. a balanced diet, safe environment, clean water, and adequate health care (preventive and curative) for all people, and the knowledge needed to care for and ensure a healthy and active life for all household members."

Impact of trade liberalization and globalization:

Opening of the markets will impact both developed as well as developing economies. "Trade liberalization can help in poverty reduction through reduced trade barriers such as tariffs and quotas, reductions in output price protection and input subsidies, privatization of agricultural marketing and trade, and increased reliance on markets rather than planning and the public sector" (Rosegrant, 2010: 28). It is also possible that trade liberalization and market dependence will exclude those who do not have adequate purchasing power. A balance is needed here between reliance on market forces for efficiency increases and equity considerations that prevent market forces from marginalizing those with no money. In addition to impact on agriculture, trade liberalization impacts livestock trade. Since specific trade agreements significantly change the patterns of agricultural production and livestock, it also impacts water use. For example, change in Multi Fiber Agreement (MFA) has phased out quotas on export and import of textiles in different countries. Currently, China is the largest producer and exporter of textiles, but the changes in MFA will increase competition for China. To maintain this position, China will have to depend on availability of water to keep up with the agricultural production (Rosegrant, 2010).

On one hand globalization is allowing for transfer of knowledge and experience to deal with water problems and increasing productivity from developed to developing countries but on the other hand globalization is also probably transferring the notions of Western thinking, consumption patterns and institutions (which might not fit local culture and customs) and might not be appropriate. Mostly by the time it is realized by local people that Western paradigm/philosophies/thinking or institutions adopted based on Western thinking will not work in their local settings, it may be too late and has likely created more problems than solving the issues (Ringler, 2010). It is important to take local culture and customs into consideration when transferring knowledge or institutions between regions and cultures.

Some solutions:

Climate smart agriculture[1]:

Why climate smart agriculture?: Until recently, the agriculture sector was not part of the main climate change discussions — this sector was seen more as a victim to change in climate related factors such as: temperature, precipitation etc. The dependence of agriculture on climate has been known probably since humans started farming but climate change has shown how deep this dependence is. However, now the sector has become a part of climate change discussions — it is seen as a greenhouse gas emitter and a part of climate change problem itself (linkages also shown in IPCC fifth report), which led to coining of the term "climate-smart agriculture." Agriculture contributes to the increase of both methane and nitrous oxide accounting for nearly half of anthropogenic methane gas and 60% of nitrous oxide gas. Now the farmers have to move beyond from just planning for occasional floods and droughts to be ready for more frequent extreme climatic events, support the ever growing population and also minimize impact of agriculture on environment and climate change. This is why climate smart agriculture has become important.

What is climate smart agriculture?: As defined by the FAO, climate-smart agriculture consists of three pillars — mitigation, adaptation and climate smart development. Mitigation means dealing with GHG emissions from the agricultural sector to reduce agriculture's climate footprint, adaptation would be adapting and building resilience to climate change and finally climate smart

Table 2: Climate compatible development for food security would entail

Identifying drought or flood resistant varieties of crops (in this case rice)	Increase income generation and climate impacts per unit area through agroforestry, organic cultivation	Diversify food basket to include meat, eggs, milk, aquatic products, fruits, vegetables etc
Identifying change in cropping season (and educating farmers about it)	Exploring non-farm sources of income or livelihoods	Change crop yield per Hectare OR change crop type to suit climate changes
Identifying alternative sources of irrigation (or water sources) and efficient water management/ irrigation practices	Local value addition of agro products and linkages to value chain	Train farmers to ensure they understand the new developments i.e. they have information on new crop varieties, change in growing season, better water management
Exploring diversification of crops (or alternative crops) and crop rotation	Developing set of indicators linking food security and climate change	Understand the critical role of gender in food security, particularly the broader issues of women's rights and access to resources (including land and water) since this impacts ability of women to produce food for food security at household level

(Source: World Bank, 2012; FAO, 2011)

1) This section is based on a Working paper by (Grover) for CDKN.

agriculture (development) would also mean sustainably increasing agricultural productivity and income to secure food security in the region.

Climate compatible development in agriculture for food security is also important for poverty alleviation and to protect livelihoods of (especially) small-scale farmers. Agriculture is an important activity for farmers in the developing countries, like Laos PDR and the Philippines in Asia, where it is their main livelihood and source of income. Most of the small-scale farmers depend on the harvest for their food needs and only sell part of their crop harvest for money. Hence there is a critical linkage between agriculture, food security and poverty in the rural economies of the developing countries like Laos PDR and Philippines in Asia.

Agriculture is also directly linked to climate (change) because what can be grown and how much harvest is produced depends on the local temperature and rainfall (besides other local environment such as economic, cultural, and soil conditions etc.). Adaptation to changing climate (i.e. change in local temperatures and rainfall) is a key to regional as well as global food security. As agriculture is also one of the main greenhouse gases contributors, climate compatible development that takes this factor into consideration will be a key. One of the ways to promote climate compatible development (especially for poor and vulnerable people) is to have policies that would support such a development. One of the examples of climate smart agriculture includes "System of Rice Intensification" (SRI) tried in various places including Vietnam. Globally, the irrigation of rice uses 40% of total water used in irrigation and also contributes to about 10% of anthropogenic methane. SRI method recommends alternative wetting and drying of the field (which gives time to the soil to dry. This prevents generation of anaerobic bacteria leading to reduction of as much as 90% of methane) and organic manure. SRI also requires seedlings to be placed in a grid pattern which allows plants to make best use of the light, nutrients and water available to ensure good yields. Integrated pest control is also recommended. First tried in Cambodia this has also been used in Vietnam. Smallholder farmers in Cambodia have reported doubling of yield while cash expenditure has been reduced by 95%. While farmers using traditional practices have lost money in growing rice, those using SRI have netted incomes ranging from US$100 ('mixed' SRI) to US $700 (fully organic SRI) (Neate, 2013).

Climate Smart Agriculture Technologies:

Hydroponics:

"Hydroponics is a soilless method of growing plants in which all necessary nutrients are fortified in water with the mechanical support of inert substrata" (Premanandh, 2011, p. 4). One of the advantages of using this technology is effective water use (reduced water consumption) followed by the fact that growing season can be extended for the whole year. Hydroponics technology also increases crop yield. There are certain disadvantages to this solution: higher capital costs, energy inputs and higher degree of management skills required for production with hydroponics (Premanandh, 2011). This type of technical solution is best implemented in the areas which experience constant floods and they can use access water to their benefit. This has been tried in Bangladesh (Premanandh, 2011).

Biotechnology

"The Convention on Biological Diversity defines biotechnology as any technological application that uses biological systems, living organisms or derivatives thereof, to make or modify products or processes for specific use" (Rosegrant, 2010, p. 33). Biotechnology can help in dealing with issues such as drought and salinity as seen in Table 3 (source: Rosegrant, 2010, p. 33).

Table 3: USE OF BIOTECHNOLOGY

Issue	Response
Research Needs	Understanding genetic and physiological determinants Perception of stress Signal transduction Gene activation Protein expression
Likely impacts	Crops for marginal land Increased productivity Crops with less chemical and fertilizer inputs Crops for saline soils
Policies	Education for water use Public participation in promoting research Long-term commitment and continuous support Private and public sector cooperation

(Source: Rosegrant, 2010)

Transgenic technology

"Transgenic technology is a discipline of biotechnology in which genetic material from one organism is transferred to another without sexual mating. Commercial production of transgenic crops started in the mid-1990s and the technology claims to have the potential to boost food security by offering better yields in shorter times as well as higher income to farmers. As a result, an impressive growth rate of up to 80-fold increase has been observed during 1996–2009" (Premanandh, 2011, p. 5).

Improving efficiency of water use

As discussed by Kubursi (2012), "water productivity (WP) is not restricted to higher output levels per unit of water. The return or the benefits derived from each cubic meter of water consumed has many dimensions. This return may be biophysical (grain, meat, milk, fish etc.), socio-economic (employment, income), environmental (carbon sequestration, ecosystem services) or nutritional (protein, calories etc.). Most of the water is consumed through evapotranspiration and is therefore "unrecoverable". Recycled water is not considered to be consumed or depleted" (p. 17). Improving WP will depend on factors such as scale of operations and the objective of the user. For example, at the field level biophysical WP should be maximized while at the farm level economic returns should be maximized. WP can be improved by implementing modern technologies, adopting more efficient water management methods such as supplemental irrigation (drip and sprinklers deliver better results than traditional surface irrigation) and water harvesting, improved cropping patterns and using improved germ-plasma. Rainfed agriculture still has the highest potential for increases in water productivity and food production in the region's agro-ecosystem given its extensive use (Kubursi, 2012, p. 17). To achieve food security, integrating water management and improved agricultural practices will be important.

Soil improvement

Crop production depends on the health of the soil and as discussed above, chemicals are reducing the soil fertility decreasing crop production. Climate change is also impacting the availability of soil moisture for plant growth. Some of the basic principles for climate change adaptation and mitigation for soil include improving water storage capacity of soil, controlling soil erosion, improving soil structure by adding organic matter, boosting nutrient management and managing soil organic matter for soil carbon sequestration. Land use planning should be done in a way that intensive land uses are not expanded into vulnerable land where soil organic carbon stocks are less resilient (Food and Agrilculture Organization of the United Nations, 2013).

Farmers should be encouraged to practise integrated soil-crop-water management to improve the soil's nutrient retention capacity and enhance soil biota. This would include things such as direct seeding without tillage, improved protective soil cover, crop diversification through crop rotation, integrated soil fertility management, proper management of nitrogen and good irrigation methods (Food and Agrilculture Organization of the United Nations, 2013).

Crop production

Crop production has evolved since the domestication of crops about 10, 000 years ago. However, the best example is that of Green revolution of 1960s, which involved growing of high-yielding crops with a chemical package and irrigation. Although at that time it saved millions of people from hunger, it also led to land degradation, depletion of ground water and contamination of soil and water. In 2011, the FAO has come up with "sustainable crop production intensification." "It means a productive agriculture that conserves and enhances natural resources through an ecosystem approach that capitalizes on natural biological inputs and processes. It reduces the negative impacts on the environment and enhances natural capital and the flow of ecosystem services. SCPI also contributes to increasing systems' resilience—a critical factor, especially in light of climate change" (Food and Agrilculture Organization of the United Nations, 2013, p. 196). The focus on this type of farming is to maintain healthy soil, cultivating a wider variety of crops with crop rotation, using good quality seeds, adopting integrated management for pests and weeds as well as managing water more efficiently. One of the examples is "system of rice intensification" which is based on the principles of developing healthy, large and deep root systems that can better resist drought, waterlogging and rainfall variability (potential impacts of climate change variability) (Food and Agrilculture Organization of the United Nations, 2013).

Providing enabling framework — Helping governments and policy makers move existing agricultural policy towards climate smart approaches —

Policies should be able to provide guidance and actions to deal with food insecurity issues — to provide food for healthy living. Food is not seen as a human right but mainly as an economic commodity, which can be best seen in the spike in food prices in 2008 which exacerbated the 2009 global economic crisis. Both developed and developing nations were hit by this food crisis. Subsidized food production and direct food relief helped citizens of developed nations while developing nations did not see any such actions. Similar actions in developing countries can bring immediate relief while long term strategies should include measures such as lower domestic food prices which can be brought about by change in food policies, tax cuts on staple food imports and providing more jobs to the vulnerable population (Premanandh, 2011).

Virtual water:

Virtual water "... is defined as the volume of water used to produce agricultural commodities, and can be measured as crop water depletion or as irrigation water depletion. Crop water depletion is computed from effective precipitation (soil water or "green" water) and irrigation ("blue" water). This includes crop evapotranspiration and losses due to reservoir evaporation, percolation to saline aquifers and pollution. Irrigation water depletion is the volume of "blue" water used during crop production, and is smaller or equal to crop water depletion" (Rosegrant, 2010, p. 27). It makes sense that water is optimally utilized and especially in the areas where it is scarce. It can be argued that it will make more sense to import food crops in water scare area and use the water saved for competing uses.

In the end, for water security, it makes sense that crops and goods that require intensive water use should be imported in a region that is water scarce; however, from the point of view of food security (where as discussed in the paper earlier countries have taken extreme steps to buy land to feed their population) does it make sense to depend on exports for food, where some countries can hold the other countries hostage for agreeing to their terms and conditions in an event of a conflict or war?

Food loss prevention and control:

Since food losses account for a lot of wastage, especially in case of fresh fruits and vegetables, it makes sense for the governments to invest money in building facilities to prevent this loss. It would involve mainly addressing infrastructure issues (such as building cold storages) and connecting farmers to markets by better transportation system (Premanandh, 2011).

Payment for eco-system services:

Successful policy implementation case study with local stakeholder's participation

This section will give a case study where government policies helped the local farmers as well helped prevent further degradation of wetland in Japan. The case study is about the wetland Kabukuri-numa, (located in Tajiri-cho, Osaki-city, Miyagi with an area of approximately 150 ha of which about 100 ha is dry river bed and about 50 ha is surface water). Kabukuri-numa is not only home to about 220 bird species but is also a landing spot for migratory birds (white-fronted geese) and it is reported that about 95,000 geese visited this wetland in 2013.

However, the wetland was facing the problem of environmental degradation caused by the over-concentration of the wild geese—there was not much rice paddy farming done during winter season and a lot of migratory birds would cause issues related to water contamination. Therefore, the local government suggested carrying out "Fuyumizu-tambo" in 2003. It is a method of rice growing which differs from more conventional methods, and necessitates the filling of the rice field with water during the winter season (when rice paddy farming is usually not carried out). The purpose of filling the rice fields is that water will help uphold the environment of wetland—birds feed on the weeds (meaning herbicide was no longer required) and the bird droppings in the water adding soil enriching phosphoric acid. Birds can no longer roost in the fields but they help enrich the soil and in getting rid of the weeds, which contributes to environmental preservation of Kabukuri-numa.

This project shows that if the policy is implemented in a right way it can have many benefits. For example, in this case (Takenaka, 2008):

i. If the farmers agreed to cooperate with government scheme of "Fuyumizu-Tambo", their rice paddy farms got registered with Ramsar Convention of Wetlands on November 8th, 2005 (which provides payment for eco-system services). This means the farmers have their fields marked with a brand which gets them a higher price for the rice and it also helps their future generations (gives them an edge in the competing market).
ii. Farmers had to agree to organic farming with financial support from the government. Organic farming helped preserve the environment in the wetlands.
iii. Also, farmers had to submerge their rice fields in winter (non-growing season) with water. As discussed above (and worth repeating), the purpose of filling the rice fields is that water will help uphold the wetland environment—it provides a habitat for fungi, sludge worms, frogs which help make soil fertile, birds feed on the weeds (which means herbicide is no longer required) and the bird droppings in the water adding soil enriching phosphoric acid. Birds can no longer roost in the fields but they help enrich the soil and in getting rid of the weeds, which contributes to environmental preservation of Kabukuri-numa. These activities help farmers to produce higher quality rice without using chemical fertilizers and herbicides thus promoting the concept of living in harmony with nature (Payments for Ecosystem Services, 2010).
iv. Although farmers initially did not like the idea of "living with" the geese (which were seen as pests that destroy farms and eat rice crops), as the farmers understood

the idea, they agreed to go along with it and it has helped restore the wetland. Currently, there are 40 ha rice paddies using for "Fuyumizu-Tambo". The environmental preservation of the wetlands seems to be carried out smoothly by the farmers in co-operation with the local government, although those who practice "Fuyumizu-Tambo" do not necessarily agree with the central idea of the local administration to carry out such practice.

This case study also reinforces the point that stakeholder involvement and participation is important for successful implementation of a policy. The stakeholders can have slightly different reasons and goals for implementing the policy but they support and reinforce each other's agenda which helps in achieving a sustainable solution.

Climate smart landscapes approach:

"In a landscape approach, the management of production systems and natural resources covers an area large enough to produce vital ecosystem services and small enough so the action can be carried out by the people using the land and producing those services... More recently, the term 'landscape approach' has been redefined to include societal concerns related to conservation and development trade-offs. It also includes increased integration of poverty alleviation, agricultural production and food security. The approach puts the emphasis on adaptive management, stakeholder involvement and the simultaneous achievement of multiple objectives."[2] Essentially, this implies that there needs to be an integration of management of agriculture, forestry, fisheries and livestock to achieve a holistic landscape view and thus climate smart agriculture.

Agroforestry

As defined by Premanandh (2011), "Agroforestry refers to the deliberate integration of trees, agricultural/horticultural crops and/or animals on the same land··· Although practices differ from country to country as farmers adapt to needs and circumstances, the main objective is to maximise the use of available land in an effective way while providing ecological and environmental benefits" (p. 3). Advantages of agroforestry include:

1. It retains soil organic matter for soil fertility
2. Deep-rooted trees increase soil microbial activities
3. Contributes to tropical biodiversity conservation improving farmland as well
4. Better carbon sequestration
5. Improves water use efficiency

Since a large number of local people still practice this kind of integrated framing, policies should encourage preserving indigenous knowledge to enhance local farming practices.

Climate smart livestock

In case of livestock climate smart approaches there is a need to consider both production systems and supply chains. Some mitigation options are linked to better feed production, enteric

2) Sunderland (2012) as quoted in http://www.fao.org/docrep/018/i3325e/i3325e02.pdf

fermentation and manure management while adaptation options are related to organic matter and nutrient management, and income diversification. Attention also needs to be given to restoration of degraded grasslands through sustainable grazing management practices i.e. reductions in grazing pressure on land where overgrazing is a problem; sowing of improved pastures; and better pasture management (Food and Agrilculture Organization of the United Nations, 2013).

Climate smart fishing and aquaculture

Some basic principles would include prevention of overfishing, minimization of negative impacts on aquatic ecosystems and local communities but the need is to move towards more of an ecosystem approach to fisheries and aquaculture. The focus should not be just on production and management of commercially important species but to plan, develop and manage fisheries and aquaculture in a way that will balance diverse societal needs and also take into account the knowledge and uncertainties associated with biotic, abiotic and human components of ecosystems and their interactions (using integrated management approach within ecological meaningful boundaries). Early warning systems and educating local communities about climate variability and its impact on fisheries (source of protein and livelihood) is part of the policy and package of measures for making this sector climate resilient. There are different ways of making fishing and aquaculture climate resilient. One good strategy was (is) followed in climate-smart tuna fishing in the western Pacific where El Nino and La Nina events were affecting tuna production. For sustainable tuna fishing "vessel day scheme (VDS)" was formed which is something like a cap and trade scheme. Under this scheme member countries are allocated vessel days for tuna fishing based on the historical average pattern of fishing (adjusted periodically) and members can trade fishing days between themselves. The VDS not only takes climate variation into consideration for allocating fishing days but it also allows the fishery to adapt to climate change. The climate smart approach to this sector is still evolving and it will be critical to build capacity and improve performance to improve aquaculture management to deal with climate change uncertainty (Food and Agrilculture Organization of the United Nations, 2013).

Climate risk management integrating into agricultural development—

Climate risk management involves developing crops that are flood and drought resistant.

Promoting gender

Promoting gender is a critical differentiator and component of effective CSA approaches. Although gender is a critical factor in climate smart agriculture and achieving food, especially in rural areas, yet a lot needs to be done in integrating this into CSA.

Case study:
Impact of climate change and adaptation strategies in Laos and the Philippines:

Lao and the Philippines (Sumernet)[3]:

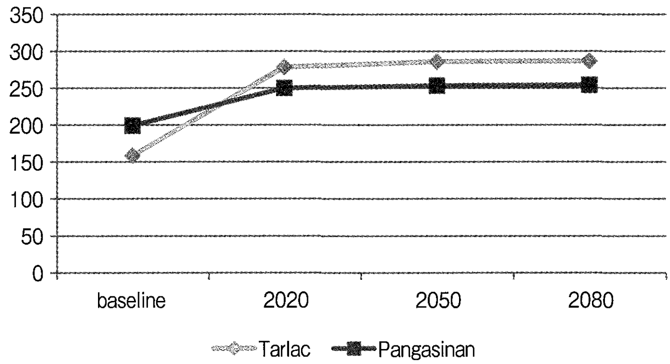
Context and challenges: Lao PDR and the Philippines are two Asian countries that are vulnerable to climate change impact. As noted in Thomas (2013) the Philippines is among top ten countries worldwide at the risk for both climate change and disasters. The Philippines usually gets hit by an average of 20 typhoons a year; the intensity and frequency of these typhoons is increasing. Also, about 0.5% of GDP is lost to natural disasters each year and this is expected to increase to 1 to 2% because of climate change events. In 2009, Ondoy and Pepeng cost Philippines economy 2.7% of GDP (Thomas, 2013). Farmers in Pangansinan and Tarlac reported that typhoon and continuous intense rain are the most frequent climate-related hazards that they have encountered. These brought farm income losses that account for 70-90% of total value of losses in lowland and upland rice farms in the two provinces (SUMERNET, 2013). Lao has also seen 33 major floods since 1966 but occurrences and intensity of floods has increased since 2010. In Aug 2011, typhoon "nok ten" devastated 3 provinces in southern part of Lao while in Aug 2012 flooding was at a historic level. Floods and droughts have caused damage of US $ 477, 085, 101 and US $ 87, 262, 715 respectively (Rimes, 2011; Soukkhy, 2012).

In both Lao PDR and the Philippines, agriculture is still the main driver of the economy, a dominant livelihood source and employs a high proportion of the labor force. Rice remains an important staple diet and thus in the case of natural disasters significant losses are sustained, rise in poverty including less access to food and low purchasing power. This dependence is particularly prevalent in the rural areas where many people reside, thus complications brought by climate change may compound current vulnerabilities in the sector. As analyzed by Thomas (2013) there is a direct linkage between rainfall, agriculture production, real income which affects consumption and food security. Rainfall affects consumption through its impact on real income. Agricultural income is likely to be most sensitive to the environment, with the marginal productivity of labor being affected by rainfall shocks affecting profits of farmers as well as wages of agriculture related wage workers. Less rainfall would generally lead to less production that will not only impact rice producers but will increase the rice price impacting non-agriculture households as well.

Research Analysis: Results of SUMERNET (2013) study have suggested that there will be minor changes in temperatures but significant changes in rainfall in the region (main changes in the rainfall pattern has been estimated till 2020 with some changes further till 2080. This has been

3) This section is based on the CDKN funded SUMERNET project, "Climate Change Implications To Food Security And Livelihood Of Small-Scale Farmers" implemented by University Of The Philippines Los Baños, Philippines and National Agriculture And Forestry College, Lao PDR summary included in Working paper, "Food Security and Climate Compatible Development: An Asian Perspective" by Velma I Grover for CDKN.

Figure 2: rainfall changes in Tarlac and Pangasinan in the Philippines



(based on data in SUMERNET, 2013)

Figure 3: Change in rice production in Pangasinan, the Philippines

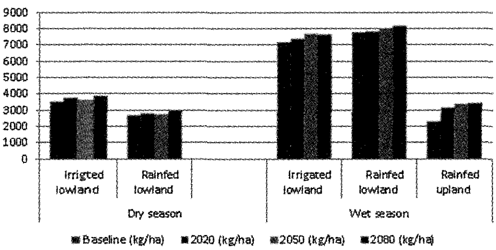


Figure 4: Change in rice production in Tarlac, the Philippines

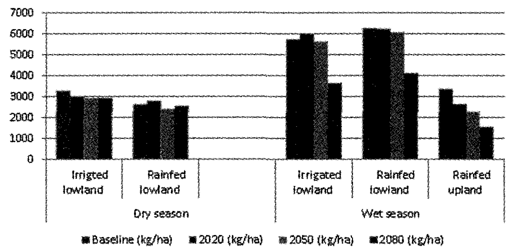


Figure 5: Change in rice production in Luang Prabang, Lao-PDR

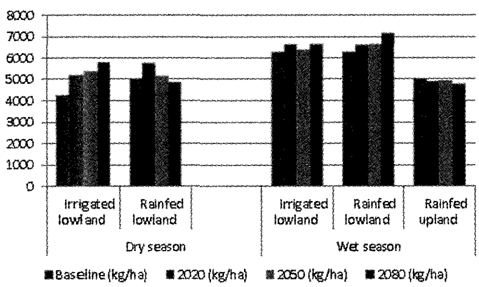
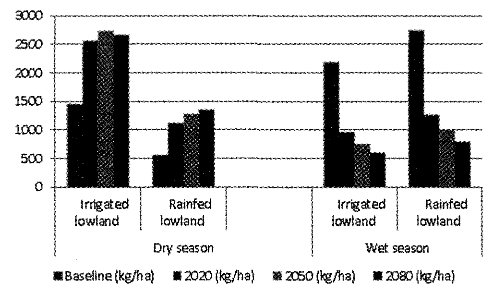


Figure 6: Change in rice production in Savannakhet, Lao-PDR



shown in Figure 2 for the two provinces in the Philippines). Essentially, this will have an impact on the rice production (see Figures 3, 4, 5 and 6). As shown in the study (and Figures 3, 4, 5 and 6) there will be a significant decline in projected rice yield in Tarlac and Savannakhet that will consequently affect farmers' income and their ability to buy food, thereby, adversely affecting food accessibility. Reduction in yield will also mean reduction in the amount of rice produced that will be saved for home consumption. On the other hand, the projected increase in rice yield in Pangasinan and Luang Prabang will mean greater food accessibility either through the market or from own production.

Adaptation strategies during water shortage: Farmers respond differently to different climatic conditions. *In the Philippines*, some farmers explore alternative sources of water while others adjust their farming. Under extreme water shortage conditions, such as long dry spells and droughts, more than 70% of the farmers are compelled not to plant rice during the dry season. However a more serious problem is that having been used to typhoon events, which average 20 per year, the majority of the local households believed that climate variability and extreme climatic events are a matter of fate and beyond their control. Thus, most of those who are exposed to extreme climatic events have learned to live with these disasters and have no long term adaptation plans. When crops are damaged by typhoon and flooding, their response is to repeatedly re-plant whenever weather conditions permit. *In Lao PDR,* on the other hand, farmers practise intercropping and plant different crop varieties to reduce the impact of drought. Farmers received support from the government through tax reduction or exemption depending on the extent of damage, to recover from the effects of drought.

Conclusion:

The recent volatility of international food prices have brought food (in)security debate right to the forefront of food policy issues and debates. On one hand, world price shocks led to high domestic volatility, on the other hand this also caused, in some cases, food producers to lose their investments. These fluctuations also impact small-scale farmers who cannot assume risks and thus do not invest in newer technologies leading to lower production. The real vulnerability of food security is, however, due to climate change—changing weather patterns, extreme events such as floods, droughts, hurricanes—which impact small farmers and poor consumers more (FAO, IFAD and WFP, 2013).

It is not only the volatility of food prices, but food demand/supply swing also play an important role in the food security equation. For example, China was a food exporter up to 2006 but is now the world's leading food importer by 2014 to feed its burgeoning population (Brown, 2014).

One of the ways to deal with food (in)security issues is to diversify the food basket to include fisheries, aquaculture and forest products into the diet. About 15-20% of all the animal protein can be contributed to aquatic animal consumption, this diet is considered highly nutritious and also a good supplement of essential vitamins and minerals. Forest products also include some very "nutritious foods such as leaves, seeds, nuts, honey, fruits, mushrooms, insects and animals. In Burkina Faso, for example, tree foods constitute an important share of rural diets. It has been reported that 100 grams of a fruit from the baobab tree correspond to 100 percent of a child's recommended daily allowance of iron and potassium, 92 percent of the recommended daily allowance of copper and 40 percent of the recommended daily allowance of calcium" (FAO, IFAD and WFP, 2013, p. kindle location 367).

In order to achieve food security, proactive policies are needed. Based on the discussion in the paper some of the policy recommendations include: change the way of thinking about water and agriculture. Essentially, this means going away from the large scale investments to investing to improve human and institutional capacity; and improving water management and infrastructure. Governments should also invest in finding ways to increase the productivity of water. The focus of new policies and reforms should be on improving water governance and also improving access to agricultural water and its use; managing agriculture to enhance eco-system sciences; and improving access of farmers to markets. The way forward is climate smart approaches to agriculture, livestock and aquaculture. Although innovative technical solutions are needed to deal with current food security issues, one of the key issues will be to improve water efficiency. As discussed in the paper, on integrated approach is best for improving climate resiliency in the climate variability and uncertainty times.

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