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Food Security and the Disappearance of Glaciers:
Impacts and Adaptation Options in Central Asia

Interdisciplinary Term Paper

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Abbreviations

CIWEM	The Chartered Institution of Water and Environmental Management
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
IPCC	Intergovernmental Panel on Climate Change
ICARDA	International Center for Agricultural Research in the Dry Areas
SIC-ICWC	Scientific-Information Center of Interstate Coordination Water Commission of Central Asia
UN	United Nations
UNEP	United Nations Environmental Program
WSFS	World Summit for Food Security

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Abstract

Global warming is leading to accelerated glacier melting around the world. The effect of glacier melting may be negative for food security in the regions that depend on glaciers for their water. Central Asia is one of such regions. Using the demand and supply framework, the authors describe the impacts of glacier melting on the food security in Central Asia and suggest several adaptation strategies. The conclusion they reach is that there are a large number of factors influencing food security in the region besides glacier melting and a key measure to improve the resilience of local populations to shocks against their food security could be through increasing and diversifying their incomes using the entitlements approach.

Keywords: climate change, glaciers, food security

Introduction

Famine and hunger have haunted humanity throughout our history (Sen, 1981; Greenland, 2005). Although the right to food was enshrined in the Universal Declaration of Human Rights in the last century (Art. 25:1, UN, 1948), 1.02 billion people - more than ever before - have been undernourished in 2009 (FAO, 2009a). This "tragic achievement" (Diouf, 2009) was also contributed to by the recent global food and financial crises (von Grebmer *et al.,* 2009**)**, which dealt yet another “double blow” to the poorest of the poor, knocking millions more down into deeper poverty (von Braun, 2008). According to the World Bank (2009), the developing countries are falling behind the goal of halving the proportion of undernourished people in the world by 2015. Recognizing these challenges, 44 participating countries in the World Summit for Food Security on 16-18 November 2009, in Rome, Italy, renewed their commitment "to take action towards sustainably eradicating hunger at the earliest possible date" (WSFS, 2009). Is a bailout for the hungry of the world in the offing?

The climate change will further aggravate the food security in the developing world (Cline, 2007; FAO, 2008a, 2009b). A key impact of climate change on food security will be through increased water scarcity (Fischer *et al.,* 2007). This effect will be especially severe in the regions of the world which rely on glaciers and seasonal snow for their water supply (Barnett *et al.,* 2005). Since water resources are essential for achieving food security (Hanjra *et al*., 2009), it is critically important for these affected countries to undertake actions to adapt to disruptions in their future water supplies.

Central Asia[1] is one of such regions that strongly depend on glaciers for their water. The disappearance of glaciers and disruptions of water supply may negatively affect the livelihoods and food security of people in the region. The effect might be especially hard on rural populations, which strongly rely on irrigation water for agricultural production - the main source of their livelihood. Agriculture is a major source of employment in the

[1] Under the Central Asian countries we include here Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan.

region (ADB, 2008). Agriculture remains an important contributor to the Gross Domestic Products (GDP) in almost all of the Central Asian countries, except Kazakhstan (ibid.). As a case study in the discussion part of this paper, we review the possible effects of glacier disappearance on food security in Central Asia, and also propose some adaptations measures.

Problem definition

Glacier disappearance: bad news in water supply when demand is skyrocketing

The Earth has substantial water resources. After all, three fourth of the planet are covered by water. However, only 2.5 per cent of this water is fresh and good enough for human use (Peter *et al*., 2003). Moreover, three fourth of this fresh water are locked in the glaciers, mainly in Antarctic and Greenland ice sheets (ibid.), about 79% of which is only in East Antarctic (Wagner and Melles, 2007). Even though “the global average withdrawal of fresh water was 9% of the amount that flowed through the world’s hydrologic cycle in 2000”, it is also clear that humanity will not be able to use 100 per cent of all the available freshwater resources, as the “the rest of creation also has to live off the water” (The Economist, 08.04.2009). In many parts of the world, glaciers are an important source of freshwater for agricultural, industrial and domestic use (Barnett *et al.,* 2005). Globally about 40 per cent of people rely on glaciers for their water (Peter *et al*., 2003). For example, Himalayan glaciers alone are the source of water for 1.3 billion people in Asia (Owen and England, 1998). In addition to water for irrigation, domestic and industrial use, glaciers also provide with such benefits as ground water recharge, scenic or recreational opportunities (Chen and Ohmura, 1990).

Human activities are leading to rapid accumulation of greenhouse gases in the atmosphere resulting in the increase of mean global temperatures (IPCC, 2007; Ramanathan and Feng, 2009; FAO, 2008a). Global warming is altering the freshwater dynamics in the world. It is further aggravating the already existing high unevenness of fresh water distribution in space and time (Bates *et al*., 2008), causing increased incidence of floods in some areas and droughts in the others (Cook *et al.*, 2004).

Glaciers react very sensitively to global warming (Oerlemans, 2000), and thus, the freshwater resources in glaciers are at the forefront of climate change impact (Cook *et al.,* 2004, Oerlemans, 2000). This is because temperature increases in higher altitudes are faster than in lower altitudes (Bradley *et al*., 2006; Kock *et al*., 2009). The melting of mountain glaciers could increase short-term water availability for human use, but would mean severe water shortages in the long run (Haeberli and Beniston, 1998). Projected changes in temperature will also lead to variations in seasonal river runoffs in glacier dominated regions (Barnett *et al.*, 2005). Moreover, the climate change is also affecting precipitation characteristics over the glacier areas. For example, glaciers forming the Rhine River are projected to become more rain-, rather than snow-, dominated in the future, leading to their increased melting and more flooding in the downstream areas (Barnett *et al*. 2005). Even in the short-run, the benefits of the increased runoff will be lessened by the losses resulting from floods (ibid.) Already, glacier melting is leading to multiplication of mountain lakes, which, being unstable, can have devastating flooding effects on the communities living nearby, and in some cases, like in Bhutan, can threaten the whole country (Nayar, 2009)

Melting of glaciers around the world is intensifying, and some have already started disappearing. As a whole, different studies indicated that with on-going climate change, the mountain glaciers might disappear within 20 to 50 years time (Hoelzle *et al*., 2003; Oerlemans and Nick, 2006; Haeberli *et al*., 2007), severely impacting the water supply in their basin areas (Bradley *et al*., 2006). To give a few specific examples, IPCC (2007) indicates that by 2035, the Himalayan glaciers will probably have melted away[2]. The glacier coverage of Mount Kilimanjaro has recently been reported to have decreased by 85 per cent since 1912 (Thomson *et al*. 2009), and may completely disappear by 2033

[2] Certainly, this particular hypothesis has been now proven to be highly exaggerated.

(ibid.). Bradley *et al.* (2006) warn that in tropical Andes, glaciers may soon also fully disappear.

Meanwhile, the humanity's demand for freshwater is exponentially increasing. This increase has been strongly pushed up by the rapid population growth (Peter *et al*., 2003; Bates *et al*., 2008). If the world population has increased twice over the last 50 years, the water use, in fact, increased by four times (Sheele and Malz, 2008). Irrigated agriculture makes up the major part – 70 per cent - of human demand for water (Fischer *et al.*, 2007). Increasing incomes and more water-intensive consumption and lifestyles around the world are further adding to the freshwater demand. As a result, every fifth person in the world is already affected by a lack of water (Lozan *et al*., 2008).

Glacier disappearance: implications for food security

The country's access to water is positively related with its food security (FAO, 2003). Even in cases when overall water availability is sufficient, uneven rainfall or unreliable access to water can lead to food insecurity, and drought is the most important cause of food shortages in the developing countries (ibid.). Ironically, floods are another major cause of food insecurity (ibid.).

In the short- and medium-run, glacier melting results in higher river runoff (Barnett *et al.*, 2005), thus, *a priori*, providing with more favorable conditions for irrigated crop production. In many cases, however, this may also lead to flooding events and loss of crops, soil erosion, especially in sloping areas (Cruz *et al.*, 2007; Hagg *et al.*, 2007; Owen and England, 1998), negatively impacting the food production in mountainous areas around the world (Peter *et al*., 2003; Owen and England, 1998). In downstream areas, early peaking in the glacier melting will provide more water then may actually be required earlier in the season, but much less water during the crop vegetation period, when sufficient water availability is critical (Peter *et al*., 2003). More water availability may also provide with disincentives for costly, but eventually necessary, investments in greater water use efficiency.

In the long-run, disappearance or dramatic decline of glaciers can cause considerable losses of potential water supply for human needs. Since food production accounts for a major part of freshwater use (Fischer *et al.,* 2007), disappearance of glaciers and consequent drop in water availability will significantly threaten food security, especially in regions where major part of freshwater resources come from glaciers.

Impact of glacier disappearance will also have other negative consequences, especially on hydropower generation. Failure of hydropower generation due to water shortage can paralyze the industry and severely affect the livelihoods of people who depend on hydropower for their energy needs (Masiokas, 2008).

Methodology and research questions

Glacier disappearance and food security: concepts and issues

Food security as a concept has quite numerous definitions (Smith *et al*., 1993; Hoddinott, 1999). The definition of food security that has been formally and widely accepted is "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life" (FAO, 1996). This definition highlights four dimensions of food security: i) physical availability of food, ii) economic and physical access to food, iii) utilization, and iv) stability of the above three dimensions (FAO, 2008).

If availability dimension highlights the continuous supply of food through producing sufficient amounts and making appropriate stocking and trading arrangements on the national and international levels, the access dimension underscores the importance of effective household and individual demand for food (ibid.). Utilization dimension of food security relates to appropriate quality of food, while availability and access dimensions concentrate only on sufficiency in the quantity of food (ibid.). Stability dimension implies that the equilibrium point of food supply and demand is not volatile. Hence, policies that target achieving food security in the country aim to reach such a stable equilibrium point between food supply and demand, which would be no lower than adequate food needs of most of the population (Thomson and Metz, 1997).

Disappearance of glaciers in the regions dependant on them for their water will negatively affect the food supply. Less water availability as input will imply less food production, all other things being equal. The relationship between food security and reduction in water supply following glacier disappearance in a low-income country, where economy largely depends on agriculture, and agriculture depends on glaciers for water, can be illustrated using Figure 1.

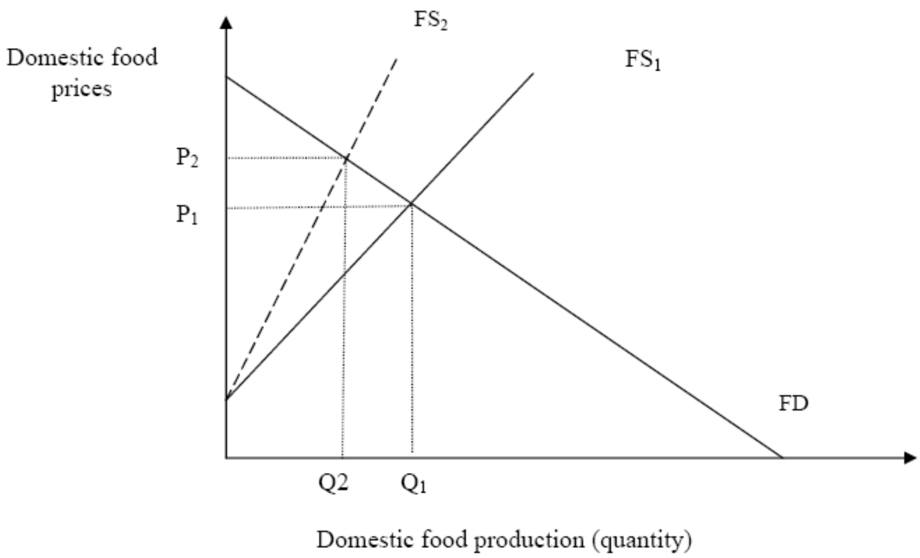

Figure 1. Effect of glacier melting on food supply

Here, FS_1 is initial domestic food supply, FD is domestic demand for food. Their interaction leads to the equilibrium at the price level P_1 and Q_1 amount of food production. The effect of glacier disappearance will move the supply line to the left to FS_2., i.e. glacier disappearance will reduce the food production in the country at all price levels.

Although with falling production and rising prices, many people may no longer afford the same quantity of food, but their need for food cannot go lower than survival level. Hence, in Figure 1, if we assume that the country was producing just enough food to be at food security level before the disappearance of glaciers (at Q_1), then the shift to Q_2 would imply that those who cannot afford price level P_2 will have to suffer from undernourishment, with all the ensuing consequences.

In fact, as Sen (1981) pointed out, hunger and famines are in most cases caused by lack of effective demand resulting from poverty, not by lack of food in the country *per se*. In our example, Figure 2 demonstrates this effect.

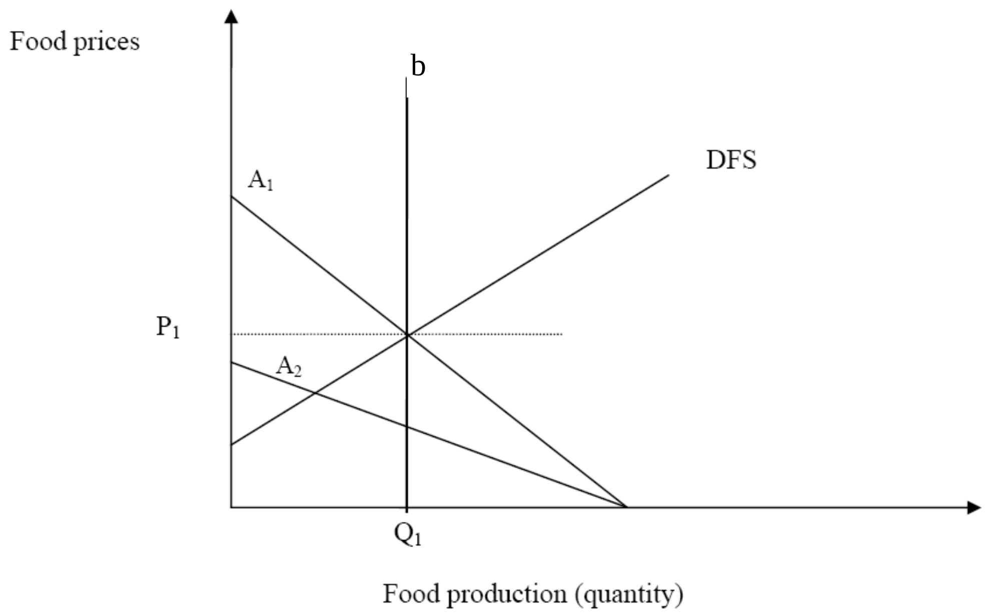

Figure 2. Effect of food prices on the food security of the poor

In Figure 2, A_1 is the average food demand in the country by all layers of society; A_2 is the food demand by the poor. Line b is the overall food requirements of the country to be food secure. The interaction of average demand and supply results in Q_1 quantity of food produced for the whole country, which is, in fact, sufficient to cover the food needs of everyone in the country. However, usually there are no “free lunches”, and only those who can afford the price level P_1 can get the food. Unfortunately, this price level does not meet with the poor's demand line, hence may lead to famine among the poor.

Regarding our case of glacier disappearance, the poor's demand line for food is flatter (i.e. more elastic) than the rich's. It means a unit decrease of supply in food (when the poor can afford some), will have larger negative impacts on the poor, than on the rich.

This situation can be avoided, or at least alleviated, using food imports from the world market at the price levels P_{w1} – which is lower than the domestic price. Here, we assume that the country has the currency reserves for this, or can at least borrow from outside (Figure 3).

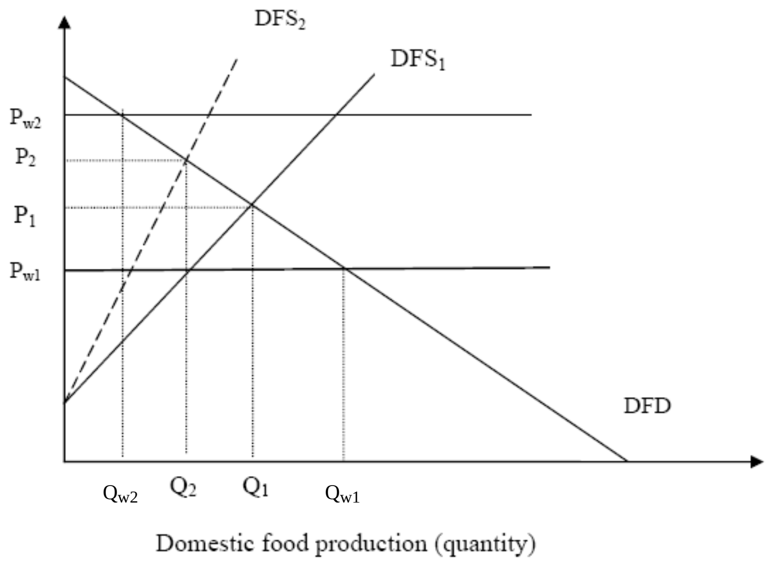

Figure 3. Effect of food trade on food supply

Conveniently, this world price level is below the price level in the country before the glaciers disappearance, so food security can be even improved (from Q_1 to Qw_1), allowing many of the poor who could not afford food before to achieve food security. As a matter of fact, it would have made sense importing some food which country is less efficient in producing than the rest of the world even before the glacier disappearance.

Agricultural policies based on comparative advantages can potentially provide more food security than dogmatic pursuance of food self-sufficiency.

At the same time, the world agricultural prices are volatile (FAO; 2009c). If the world prices, for any reasons go up to the P_{w2} level, than the country might be in a highly undesirable situation, when it may become simply unable to afford the imports to fill its food security gap. In fact, if Government does not intervene, food may even get exported despite hunger and famine inside the country.

There are many factors influencing the country's food security situation. Disappearance of glaciers in a rich country will not have the same effect as in a poor country. The demand for food is a function of such factors as i) population, ii) income, iii) cultural and individual preferences, and iv) consumer expectations. Supply of food also depends on such factors as i) climate, ii) input prices, iii) input availability, iv) input quality, v) level of technology, vi) Government regulations, and vii) producer expectations.

The problems of food security can be analyzed at three levels: national or regional level, household level and individual level (Thomson and Metz, 1997). Glacier disappearance in Central Asia – our case study area - can have major regional implications; therefore, our scale of analysis in this paper is regional. Our discussion will be based on secondary information, both published and "grey".

In the discussion part, we will follow the above supply and demand framework, where relevant, to answer the following research questions:

1. How climate change is impacting on glaciers in Central Asia?
2. How the melting and disappearance of glaciers will impact food security in the region?
3. What needs to be done to ensure food security in Central Asia under glacier melting and eventual disappearance?

Discussion

Climate change and glaciers in Central Asia: a storm of change?

In Central Asia (Figure 4), glacier melting and eventual disappearance may have negative impacts on the food security and livelihoods of people living there, as the glaciers are the major source of water in the region (Hagg *et al.*, 2007; Osokova *et al.*, 2000). Since the last 80 years, major glaciers of the region in Tyan Shan and Pamir mountains have lost 25%-35% of their area (Kutuzov, 2005; Podrezov *et al.*, 2001; Chub, 2000).

Figure 4. Political map of Central Asia

Source: Library of the University of Texas, Austin, USA. Online collections[3].

According to a larger group of researchers, the future impact of climate change on the regional water resources will be devastating and take place relatively soon from now. For example, Perelet (2007) projects that by 2050, as a result of climate change, the water supply in the Syrdarya and Amudarya Rivers may decrease by 30% and 40%, respectively. WBGU (2007), as cited by Christmann *et al.*, (2009), also indicates that by

[3] Accessed on 29 November, 2009 at http://lib.utexas.edu/maps/commonwealth/cis_central_asia_pol_95.jpg

2050; about 32% of glacier volume will have disappeared in Central Asia. Moreover, in some areas glaciers will have completely disappeared even before that time (Christmann *et al*., 2009).

According to a smaller group of researchers, summarized by Severskiy (2007), it is true that the glaciers in Central Asian mountains will recede, but they will not completely disappear under the current climate change scenarios for the hundreds of years to come. This is mainly because there is a compensation mechanism, involving the melting of underground ice in the mountains. The reserves of underground ice in the high mountains of Central Asia are estimated to be equivalent to the present day glacier resources (ibid.).

The expected impacts of glacier melting, such as seasonal and long-term runoff changes, increased incidence of extreme events, precipitation variability, are similar to other glacier-dependant regions in the world, and were highlighted in our introductory section, so will not be repeated here. Detailed reviews of the climate change impacts on Central Asia are given in Robinson and Engel (2008), Gupta *et al*., (2009) and Christmann *et al*. (2009).

Glacier melting and disappearance will strongly affect the irrigated agriculture in Central Asia. This is because irrigated agriculture consumes almost 84 per cent of annually available surface water resources in the region (Abdullaev *et al*., 2006). Annual surface water resources get completely used up even now (Osokova *et al*., 2000). In spite of this, most of irrigated areas in Central Asia are already facing high or very high water stress (Alcamo *et al*., 2003). Importantly, in Central Asia there is no physical scarcity of water *per se*. As Varis and Rahaman (2008) indicate, the countries of the region are well-endowed with water resources, for example Turkmenistan, a “desert country” (Lerman, 2009), has more renewable water per capita (12,706 m^3)[4], than most European countries. However, it is widely acknowledged that the main problem causing water scarcity is inefficient use of water (see for example Gupta *et al*., 2009, Pender *et al*., 2009).

[4] Varis and Rahaman (2008) cite this figure from World Bank, 2004. World Development Indicators. The World Bank, Washington D.C.

Most climate change modeling results agree that the temperatures in the region may increase by 1 to 2°C until 2030–2050 (Lioubimtseva *et al.*, 2005). The temperature increase in the region can reach 3.7°C by 2100 under the doubling of CO_2 levels (IPCC, 2007). It is expected that the precipitation patterns will change, with more precipitation in winter and less precipitation in other seasons (Gupta *et al.,* 2009; Christmann *et al*. 2009). The increased temperatures will raise crop water requirements to produce the same yields as today. Cline (2007) estimates that by 2080 climate change, without CO_2 fertilization effect, will have negative impacts on agricultural productivity in all Central Asian countries (from - 5 per cent to - 15 per cent), except in Kazakhstan (+ 11.4 per cent). With the CO_2 fertilization effect, however, agricultural productivity is estimated to increase in all the countries of Central Asia, from + 1 per cent in Uzbekistan up to + 28.1 per cent in Northern Kazakhstan (ibid.).

Impacts on food security

The current state of food security in Central Asia varies from one country to another. If in Kazakhstan and Kyrgyzstan, the share of undernourished in the population is insignificant, in Tajikistan, every fourth person is undernourished (FAO, 2009c). Lately, there is a trend towards improvement in all the countries.

In Central Asia, irrigated agriculture is a key source of food production (Gupta *et al*., 2009). If no adaptation actions are taken, glacier melting and disappearance caused by climate change may result in food insecurity.

Firstly, it is becoming increasingly clear that climate change projections indicated in the IPCC reports, on which Central Asian climate models are based, might have underestimated the speed and magnitude of climate change, especially in terms of mountain glacier melting (UNEP, 2009).

Secondly, even if we assume that in Central Asia complete glacier disappearance will not happen until somewhat distant future, the expected short-term effects of glacier melting (seasonal runoff shifts, extreme events) can already be detrimental for food security, especially in the mountainous areas. For instance, irrigation water has a limited value for agricultural production in Central Asia in early spring, but it is critical during the crop vegetation period in summer.

Thirdly, the population and needs for water in the region will be increasing (Christmann *et al*., 2009), but in terms of water supply under gradual glacier disappearance, the region will be approaching the "peak water".

Fourthly, coupled with the already existing problems such as land degradation, natural hazards, institutional and policy failures, inefficient input and output markets, rural poverty (Gupta *et al*. 2009), and some other factors that we indicated in Table 1, the negative effect could become quite significant.

Table 1. Major factors with potential negative effect on food security in Central Asia

Supply-side	**Demand- side**
Land degradation	Population growth
Water scarcity (caused by inefficient use)	Poverty and unemployment
Natural hazards	Rise in income inequality
Crop diseases (ex, rusts)	Inflation
Lack of inputs and agricultural machinery	Food price volatility
High input prices	Rising transportation costs
Lack of qualified agricultural labor	Monopolized distribution channels
Absence of private land tenure	Currency devaluations
Intra-regional limitations to food trade	

For example, land degradation can pose a major threat to food production in the region. Almost 48% of irrigated area in Central Asia is affected by secondary salinization

(Bucknall *et al*. 2003). In Turkmenistan, for example, almost 96% of all lands are salinized (ibid.). Land degradation is leading to: a) lower crop yields, and b) contraction of cultivated land (Gupta *et al*., 2009).

Water scarcity is another limiting factor for crop production in the irrigated areas of the region. However, as we indicated earlier, the problem is not in the physical lack of water, but in its inefficient use. Up to 50% of the irrigation water is lost in inter-farm and intra-farm irrigation networks before reaching the field (Bekturova and Romanova, 2007). In addition, significant amounts of water (up to 5,000 m^3) are used for leaching the saline lands (Gupta *et al*. 2009). On-farm irrigation in the region is based on furrow irrigation method, which uses water resources wastefully (Gupta *et al*., 2009, Horst *et al*., 2005).

Natural hazards, such as droughts, floods, frosts, heat waves, etc pose another threat to agricultural production. Climate change is expected to increase the incidence of such extreme events in the region (Robinson and Engel, 2008). For example, a drought in 2001 resulted in the loss of 16.8 per cent and 2.4 per cent of agricultural GDP in Tajikistan and Uzbekistan, respectively (World Bank, 2005). Floods can damage not only crops in the fields, but also destroy vital food distribution infrastructure, such as roads, bridges, etc, in the mountainous areas.

Crop diseases are another threat to food security in the region (Christmann *et al*., 2009). Most of the wheat varieties grown in the region are susceptible to yellow rust, and none of the varieties is resistant to all types of wheat rusts (ibid.). Even in the immediate term, the food security in the region can be negatively affected if the now famous UG99 stem rust race would spread to the region from neighboring Iran (ibid.)

On the demand side, population growth in Central Asia remains strong (Christmann *et al*. 2009), though the growth rates are decreasing (ADB, 2008). The economic growth has usually been significantly higher than the population growth in the region during the last decade, leading to gradually increasing incomes (ibid). However, in some countries of the region, the rates of inequality in incomes have also been growing (ibid.). Recent food price hikes had impacted Central Asian countries as well (Christmann *et al.*, 2009). Those countries that were externally dependant for their food supplies were affected the hardest. Generally, Alam (2008) found that if the food prices in the region increase by 5%, the level of poverty may increase by 2-3 percent.

All the factors indicated in the supply column in Table 1, reduce the supply of food from current to lower levels or/and serve as obstacles to expansion of food supply. All factors on the demand column, except population growth, reduce effective demand for food, i.e. the ability of households to purchase food. Population growth increases food demand.

Taking all this into account, adaptation to glacier melting and disappearance should not be regarded as a distant vista (or mirage), but should be brought into the immediate action horizon. Naturally, adapting to such a large-scale change would not be easy, but gradual actions should be started now. This is even more desirable since many actions that will serve as adaptation against increased water variability and scarcity under climate change may also greatly improve the agricultural sustainability and the livelihoods of people in the region at the present. Finally, we would like to underline that food security depends, as we have shown, not only on water availability, but also on a wide range of diverse factors. Hence, the actions necessarily need to make efforts to address the food security problem in a holistic manner.

Adaptation options

Glacier melting and disappearance: water management "survival kit"

A major impact of glacier melting in the short and medium term future in Central Asia would be through shifts in seasonal water supply. This will mean increased water flows in early springs and low level of water flow during vegetation periods in summer, which will have two implications: 1) increased incidence of floods in spring, and 2) lack of water for crop irrigation in summer. Thus, the challenge is to minimize losses from floods, and transfer the excessive water in spring for crop irrigation in summer. Both of these purposes can be achieved though construction of water reservoirs, which could enable to control for floods and store water until use for irrigation in summer (CIWEM, 2005). At the same time, construction of reservoirs can pose several problems such as loss of agricultural land, possible displacement of people; changes to downstream patterns and negative environmental effects (ibid.) Therefore, all these aspects should be taken into account before their construction. In Central Asia, substantial reservoir capacities already exist (SIC-ICWC, 2002). In fact, with the total volume of 64.5 km^3 , of which 46.5 km^3 of usable capacity, the presently existing 60 reservoirs in the Amudarya and Syrdarya basins have the capacity to control 78% and 94% of the run-off in these river basins, respectively (ibid). However, almost all of these reservoirs have been to certain extent silted-up during their years of operation, so SIC-ICWC (2002) estimates that the present usable capacity is 30 per cent lower. In the context of Central Asia, constructing new reservoirs as an adaptation measure to glacier melting would require coordinated efforts among the countries. It is essential here that any actions in this area strictly abide by two conditions: 1) they would not have any negative environmental impact, 2) they will not have any negative impact on downstream agriculture.

Presently, the amount of the annual renewable groundwater availability in the Aral Sea Basin is 43.48 km^2 , i.e. almost one third of the average surface flow, which is equal to 116.48 km^3 (SIC-ICWC, 2002). However, since most of the groundwater is hydraulically linked to surface flows, the groundwater withdrawal is limited to 16.9 km^3 annually, of which 11.03 km^3 are presently used (ibid.). This hydraulic linkage also makes it practically difficult to compensate any sizable decrease in surface flows by increased groundwater use.

Re-use of return waters (drainage waters from agricultural fields and domestic and industrial sewage waters) to alleviate water stress is a more feasible option. Presently, the annual flow of return waters is about 32.45 km^3, of which 16.77 km^3 is returned to rivers, 10.87 km^3 discharged into natural depressions, and only 4.81 km^3 re-used (ibid.). However, since the level of mineralization of drainage waters is high, their re-use may lead to increased soil salinization. Hence, efforts should be made at minimizing the negative effect of drainage waters on soil quality when re-used.

Improving the conveyance efficiency of water delivery channels is another important measure for increasing water supply for crop production. As we cited earlier from Bekturova and Romanova (2007) up to a half of water is presently lost before reaching the field.

From water to food

Improving supply of water without addressing the current wasteful levels of water use will not result in sustainable food security. In addition to actions directed at achieving stable and reliable water supply, there is a need to improve water use productivity in agriculture.

Irrigation water use can be improved by applying more efficient irrigation methods such as drip, sprinkler, cutback, discrete, micro-furrow, alternate furrow and contour furrow irrigation, use of plastic chutes for irrigation in sloping areas, more productive planting methods such as raised bed planting, as well as other crop management techniques such mulching (ICARDA, 2007). These methods have been demonstrated not only to improve water productivity, but also to increase crop yields (ibid.)

Conservation agriculture can serve as a strategic platform for combating land degradation and for ensuring food security in the region under the climate change (Gupta *et al*. 2009). Zero tillage and mulching reduce soil erosion and degradation (ibid.). Crop diversification with legumes can improve soil fertility (ibid.) Double purpose wheat varieties could be a highly useful climate change adaptation strategy in the region in terms of food security (Gupta, 2008 personal communication). Breeding of drought- , salinity-tolerant, disease- and pest-resistant, and early-maturing crop cultivars is an important research priority to ensure food security under the climate change in Central Asia (Paroda *et al*., 2007).

Although there is already a wide range of land, water and crop management technologies available in the region, potentially allowing for more efficient water use, increased crop production and improved soil fertility (ICARDA, 2007), their adoption rates are quite low. To remedy this situation, there is a need for improving land tenure arrangements, providing farmers with access to credit, strengthening extension services, improving the operation of input supply markets, creating opportunities for leasing of farm machinery.

From food to entitlements

Producing food efficiently may not be sufficient for food security if effective demand is deficient. There is a need for economic policies that expand people's "entitlements".

On the surface, economic policy is nothing more than moving the supply and demand curves (Perez, 2009, personal communication). Easily said, however, moving supply and demand curves, preferably in the right direction, is a quite difficult task, especially in the context of a poor country. Putting in place an adequate policy framework plays a critical role in achieving a sustainable food security. In the countries of Central Asia, the main reason for food insecurity, where it exists, is low income and not the lack of food *per se*. Although supply side actions, including those outlined above, to achieve food security are important, in Central Asia, in our view, the critical need is for active demand-stimulating food security policies. In that regard, the entitlements approach proposed by Amartya Sen (1981), where he develops four categories of entitlements, i.e. person's demand for food based on his/her income and assets, seems to us to be a useful framework for appropriate demand-side polices. Certainly not comprehensive, but nevertheless, below we try to suggest some specific actions for improving food security in the region using each of the entitlements.

To expand trade-based entitlements, public policy in Central Asia should invest in improving the food exchange and delivery infrastructures such as building roads, railways, ports, terminals, storage facilities, etc. It is also important that the Government ensures a competitive environment in food retailing. Needless to say, open trade in food would become essential for the food security of the region in the long-term when the glaciers might eventually disappear leading to lower internal food production.

To expand production-based entitlements, all the Governments in the region took actions for allocating land to rural households. Presently, there is a need for gradual privatization of land, as has been already done in some countries in the region.

To expand people's own-labor entitlements, the Governments should take actions to increase employment opportunities, especially in the rural areas, through both direct Government investments but also through creating favorable climate for private and foreign investment. In doing this, care should be taken for the Government investments not to "overcrowd" private investments. The Governments should also implement appropriate fiscal and monetary policies in order to stimulate small and medium size entrepreneurship. Investments should be made into health and education to increase the labor productivity.

To expand transfer entitlements, the countries of the region which are large labor exporters, i.e. Tajikistan, Kyrgyzstan and Uzbekistan, should negotiate with the host countries receiving the labor (mainly, Russia and Kazakhstan) on creating favorable working conditions for their citizens working in these countries. This may lead to the increase of worker remittances to the region. The Governments should also maintain targeted and effective safety net programs to ensure an adequate level of nutrition for the poorest layers of the society. This is especially important in the context of increased food price volatility.

Conclusion

Glacier disappearance may pose a threat to the food security in Central Asia. However, this is not the only, and perhaps not even the most important, challenge to food security in the region in the foreseeable future. Presently, the key problem for the food security in the region is not lack of food, but low incomes of the population. Therefore, although it is highly important to take adaptation measures against the negative impacts of glacier melting and eventual disappearance, it is also crucial to promote growth in real incomes of people in order to increase their resilience against shocks to their food security, including those caused by climate change and glacier disappearance.

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