Food Security and Climate Change in Central Asia and the Caucasus

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Executive Summary

While there is food insecurity in the countries that once were the "bread basket" of the former Soviet Union - mainly in Tajikistan and Kyrgyzstan, but also among poor strata in the richer countries of Central Asia and the Caucasus (CAC), other countries, e.g. Uzbekistan, are net-exporters of food. According to the IPCC, regional temperatures in CAC will raise far more (3.7 °C until 2100) than the global average (2.8 °C until 2100) and an assumed shrinkage of glacier volume by around 32 % is expected until 2050 (WBGU 2007). In some areas all glaciers will completely disappear until 2050.

High temperatures will cause serious threats for the production of main staple crops such as wheat and rice in CAC; this challenges crop and cropping systems research. Producing low-income staple crops – such as cotton and wheat – will become less profitable due to increasing transportation costs. Population growth in Central Asia is high, in the Caucasus nearly stable, until 2050. Though the CAC area is large, the relation of arable land per capita is low, in some countries extremely low and will even further decrease due to climate change, population growth and land degradation. Already now, land and water resources are overexploited. Therefore, various interventions are imperative to meet the growing food demand of the CAC population: research on heat- and drought-resistant varieties of the main food crops; change towards multipurpose and underutilized plants; better conservation and use of plant genetic resources (specifically in mountain areas with high risk of extinction); diversification of cropping systems towards more integrative systems (rotations, intercropping), heat- and drought-resistant crops and high-income fruits and vegetables; improvement of irrigation systems and water distribution, including trans-national water management; better soil and dryland management; use of IPM also for food crops; protection of and sustainable 'cooperation' with natural pollinators. As women often have a preference for horticulture and preparing food due to their traditional role, the increasing number of women-farmers is a chance to accelerate the shift towards change of crops and further processing the harvest; and the CGIAR-led research might put more focus on female farmers. As climate change will increase the number of rural poor (here loosely defined as those possessing neither land nor animals[1]), the CGIAR should adjust its strategy to address also these poorest of rural poor. An integrated strategy towards food security is needed that requires working with a wide array of partners such as those from macropolicy, from the educational and the health sectors, so that for instance programs on reproductive health or lifestyle changes that affect production and consumption patterns can be induced, and these should preferably be based on rational approaches like *virtual water* and *ecological footprint* of products.

Deciding up to which degree it is favorable to shift the national strategies from food independence towards production systems based solely on regional comparative advantages differs between countries in CAC and requires more research on single countries. But even for the better-off countries in CAC, steps to increase their market integration are favorable due to the limited arable land per capita, increased stress by climate change, and high population growth in Central Asia. The development of value chains seems highly desirable, as in-country processing of raw products would generate higher income and thus decrease stress on the environment. In high mountainous areas, food sufficiency strategies remain necessary due to high transport costs and increasing difficulties to

[1] Actually the fact, that they do not own animals or land is the reason, why usually they do not benefit from agricultural research which is addressed to farmers and pastoralists mainly. Therefore, the above informal definition might be more precise than definitions like "less than one Dollar a day". Also the poorest of the poor get income or housing often in kind, which makes it more difficult to work with this 1-Dollar-definition, used also in Human Development Reports. The UNDP-Report (2007/2008) does not even give figures on "less than one Dollar a day" for the CAC countries. In UNDP 2007/2008 some figures on poverty concerning CAC are from the late 1990ies, so it is favorable to use a definition, which at least focuses on the problem.

reach the villages due to climate change related disasters. But also in mountain regions a change concerning high income crops and towards processing the harvest is desirable. New income sources for mountain villages might be derived from herbs and pharmaceutical plants within the planned establishment of Access-and-Benefit-Sharing (ABS) aproaches in 2010 (Convention for Biological Diversity; CBD).

In all CAC countries, agriculture is more important as an employer than its actual contribution to GDP (see below). Agriculture is one of the main pillars of social stability. Therefore, a decrease of income in agricultural areas might cause rural poverty, and ultimately lead to migration to a larger extent. A common food market within CAC would buffer all partners not only against volatility of world food prices, but would also increase marketing options for farmers. The newly erected borders after independence hinder trade within the CAC. Climate change highly increases the risk of conflicts (WBGU, 2007; Christmann, 2006). Major recent studies (Stern Review on the Economics of Climate Change, 2006; WBGU, 2007) regard CAC as one of the regions with the highest conflict potential fueled by climate change. Already in the past, conflicts arose along ethnic borders in CAC. Therefore, the national and international focus on food security and climate change in CAC can also be seen as a strategy to keep peace and should be increased before the need for calling in (much more expensive) 'peace-keeping forces' would eventually arise. As the region's agriculture mainly depends on wise management of trans-boundary rivers, international agreements on water use are needed and a common renewable energy strategy in CA (solar and wind), which would decrease the demand for hydro-energy production.

Mitigation does not have an immideate effect on climate change, but on the long term mitigation is extremely important for the living conditions and food security in CAC. All arguments, which can enforce mitigation have to be used intensively. The climate change related increase of food insecurity in CAC and elsewhere might be used also as an argument for strengthening global mitigation efforts. But agricultural research dedicated to food security should also benefit from multilateral climate change funds, as food insecurity increases with ongoing climate change. The flexible instruments of the Kyoto process should be reformed to give the various global drivers of climate change - such as transport, energy, housing etc. – the opportunity to contribute adequately to the adaption of agriculture by funding research, either within Joint Implementation (JI) and Clean Development Mechanism (CDM) or by additional instruments.

It is urgently necessary to step up in quantity and quality what we call 'linear research', i.e. to increase the heat- or drought-tolerance of crops, to increase their nutrient value or to improve water productivity on the fields. However, the most challenging question for agricultural research in CAC requires new, ecosystem-oriented approaches. The steep increase of temperatures in CAC will de-couple the synchrony of inter-dependent species in ecosystems and thus attack the clockwork of ecosystems by the extinction of native species, the invasion of foreign species, pests, and weeds, by changing behavior such as the routes of migrating birds, and by changing seasonal patterns which may leave important ecosystem services such as pollination to chance. These are systemic changes, unpredictable in detail due to the complexity of ecosystems, but they can have significant consequences for agriculture and food security. Specifically once global CO_2-concentration in the atmosphere will have exceeded 450 ppm (seem as one tipping point for drastic climate change) it is likely that unpredictable, disastrous, chaotic change affects all areas: climate, water, biodiversity, transport, food security, migration and conflicts. Therefore, agricultural, environmental and policy research has to collaborate much closer to better understand these systemic changes. While the present agricultural research works along linear problems within the philosophy of "management of natural resources", the complex system characteristics might in fact become 'unmanageable' after the systems reach those tipping points. Not understanding these systems in their wider complexity and context translates into not being prepared for the chaotic disruptions those systems may experience, once the thresholds are surpassed, and this may have much more disastrous consequences for food security than temperature increase or water unavailability alone. This requires swift and early action in research; policy makers must act to provide the needed ‘work environment’ by removing the disciplinary barriers that are still particularly strong in the CAC region. Due to the extremely rapid temperature increase in the CAC region, and due to the additional increase at high altitudes, integrated agricultural-ecosystemary research in CAC could play a pioneer role, as these systemic changes in the ecosystems will probably occur later in other regions.

1. Introduction

The International Covenant on Economic, Social and Cultural Rights (ICESCR), which was adopted by the General Assembly of the UN in 1966 and came into force in 1976, explicitly regards the right on food as a human right. The World Food Summit of 1996 defined food security as existing *"when all people at all times have access to sufficient, safe, nutritious food to maintain a healthy and active life".* These two consensual statements put the zeal for food security not only in the hands of the agricultural sector and agricultural policy, but of policy in general. Food security is proximately driven by types of agricultural crops grown, droughts, pests and pathogens, the agricultural practices and the resulting yields, but underlying and more important drivers are climate change, the wellbeing of ecosystems around, demographic factors, education and changing consumption patterns, infrastructure and income inequality, social fairness within a state, and access of the poor to food (Sen, 1981). 2006-2008 the number of food-deficient people increased by at least 75 million worldwide (to 963 million) (von Braun et al., 2008; von Braun, 2008) mainly driven by high food prices. According to Alibhai the number increased even by 100 million (Alibhai, 2009). Poverty and food insecurity increase the risk of conflicts (Pinstrup-Andersen, 2006).

Food insecurity is often discussed as being a problem of developing countries only. But in transition countries such as those in Central Asia and the Caucasus (CAC), specific characteristics and legacies of the past cause vulnerability to food insecurity as well (Wehrheim et al., 2003). For instance, the partitioning of tasks between specialized producer countries (e.g. cotton in Uzbekistan, wheat in Kazakhstan) in the Soviet Union was interrupted when the Soviet system broke down. Also, the re-structuring of large-sized, industrialized collective farms into small private enterprises was (and still is) a big challenge, as the former employees need much more knowledge to run a farm by their own. The technical equipment used in the former state farms with their large field sizes is now oversized for small farms.

Environmentally, the newly independent countries pay the debts accumulated during the former plan economy that focused on high production output instead of sustainable resource use. The CAC region was an important agricultural production area in the Soviet Union and still has high potential in food production. However, some regions and large sections of the regional societies suffer from high food insecurity within the CAC region. Regarding Wehrheim's (2003) assumption that in most transition countries food insecurity will be only transitory, Tajikistan and Kyrgyzstan are and will remain exceptions, if measures taken by the countries themselves and the international donor community fail. Based on FAO (2001) Wehrheim already regarded 35-47 % of the population in Tajikistan – as well as in Azerbaijan and Armenia - as undernourished. Malnutrition of children is a widespread problem in CAC, specifically in Kyrgyzstan, Uzbekistan (IAASTD 2009b) and Tajikistan (WFP, 2008). In this respect, micronutrient malnutrition is prevalent in Central Asia; where for example, Muynak district of the autonomous Republic of Karakalpakstan, Uzbekistan, has one of the highest estimated rates of iron deficiency anemia among young children (below 5 years of age) and women in childbearing age in the world (Carli et al., 2008).

This paper will discuss the risk of growing food insecurity in CAC, the potential capacity of the region to produce food for itself and the potential to produce food for export; i.e. its potential to contribute to food security worldwide. E.g. there may be advantages for food exports from the region, for instance to India, China, Afghanistan, Russia or Europe. – Food quality, drinking water supply and quality are not dealt with in this paper. Also emergency aid measures like school and pre-school nutrition programs or utilization of food are not subject of this paper.

The frame set by effects of global warming in CAC, population growth, world food prices etc. will be described, then the potential of main staple foods, further fields of research and knowledge management will be discussed; finally recommendations are given. This paper mainly focuses on two questions:

(1) With view to climate change and population growth in CAC, is it more favorable to focus research on food independence (as preferred specifically by the governments in Central Asia) or on food security based on high income crops, value chains and better integration into the world food market? Is it possible to meet the growing demand for grain and rice only by improved breeding and sustainable land management in CAC?

(2) Climate change related disasters such as landslides and drought will increase the number of the poor, because the poor loose most in crises (von Braun, 2008) and have less chances to recover. CGIAR has the mandate to improve the living conditions of the poor, but the poorest of the rural poor often have neither land nor animal possessions, and are therefore not the target group of agricultural research. Therefore, the paper also raises the question if or how CGIAR can contribute to reducing the growth of poor in number and if or how the CGIAR can adjust its research agenda to reintegrate those excluded back into the agricultural sector.

One important aspect concerning food security and climate change cannot be discussed in detail in this paper, but should be mentioned: the necessary change of arguments concerning better management of trans-boundary rivers in Central Asia. The management of these rivers will become more and more crucial for food security and peace within this century. The argumentation concerning the management of trans-boundary rivers has to be changed, as present and past efforts failed. At present the governments discuss on the level of strategic arguments only[2], not on the level of real demand[3]. The challenge is, to create an environment, which allows the stakeholders to talk about their real demands and to identify common targets. Without a broader common vision for the development of Central Asia it will probably not be possible to improve the use of trans-boundary rivers and to solve some of the main problems of agriculture and food security in the fate of climate change. A new vision might be developed together with stakeholders from the energy sector: The CA-countries might be convinced that a common renewable energy strategy within Central Asia – like a "DESERTEC-CA"[4] - in cooperation with multilateral organizations would be favorable for all countries, for agriculture and for food security. The high potential of wind- and solar-energy in the region and a common energy market might reduce the need to extend hydropower in Kyrgyzstan and Tajikistan and to reserve water for agriculture (WBGU, 2007). Anyway hydropower will be highly affected by climate change and melt of glaciers. The CAWa-project (Research on Water in Central Asia, www.cawa-project.net) and contacts with UNECE therefore should be used as a first chance to get support for this approach.

[2] Each stakeholder insists on the amount of water he consumes now using present equipment, technologies, crops; or he insists on the amount of water, he needs for electricity, produced by present technologies.

[3] The real demand is not water; water is only one asset among others to reach a special purpose; real demand is to produce food, to generate income from agriculture, to provide jobs in agriculture and to maintain stability.

[4] DESERTEC is a newly founded project (2009). An international group of investors intends to build large plants for renewable energies in northern Africa and to export the electricity to Europe. *www.**desertec**.org/*

2. Agriculture in CAC within the global scenario

Climate Change – a real threat to CAC

The focus of the paper will be on vulnerability of the CAC region to climate change, but also on the fact that this region is also an important source of greenhouse gas emissions. Kazakhstan for instance is the 30th largest emitter of carbon dioxide worldwide, but since 2000 among the Annex I countries[5] of Kyoto-Protocol. Uzbekistan is the most carbon intensive economy globally (WRI, 2005, cited by Perelet 2007). The Usbek pro-coal-strategy[6] will fuel global warming additionally.

A rise of global average temperature by 2–3°C increases the risk of additional, qualitative changes occurring in the climate system. A CO_2-concentration of 450 ppm is regarded as the so-called tipping point for many climate-related phenomena (e.g. weakening of the the North Atlantic Current, monsoon transformation, instability of Greenland ice sheet and West Antarctic ice shield, collapse of Amazonian forests etc.) and expected to be reached around 2050 (WBGU, 2007; IPCC, 2007). Such a high CO_2 concentration will fuel global warming and lead to irreversible damages of the global ecosystems in general, to increased loss of biodiversity specifically in mountain areas (IPCC, 2002) and to an increased risk of weedy and invasive species and pests. Agriculture functions because it relies on many "ecosystemary services" and also depends on the ecosystems around it, which provide services to the agricultural sites (water, bees, natural enemies of pests etc.). "*Many of these changes adversely affect food security and disproportionately impact the poor*" (IPCC, 2001; also Sukhdev, 2008). In 2008, FAO stated with view to climate change, that "*everybody is at risk*" (FAO 2008). This is specifically the case in CAC. Warming in Central Asia will exceed global warming by about 40 % (IPCC, 2002). IPCC (2007), Stern Review (Stern, 2006) and WBGU (2007) regard this semi-arid region as one of the most vulnerable areas to climate change globally – and consequently, as one potential area of conflicts related to climate change, such as access to water and arable land and food insecurity. According to WBGU (2007), since the beginning of the 1970s the recorded air temperature in Central Asia has risen by 0.3-0.4 °C per decade – this is more than twice the global mean. Most climate change models agree that the temperatures in Central Asia will increase by 1–2 °C until 2030–2050 (Lioubimtseva *et al.*, 2005), and should CO_2 levels double from the current 388 ppm (July 2009; cf. 'CO_2 now', 2009), the region would be likely to warm on average by 3.7°C until 2100. This is above the global mean projection of 2.8 °C (IPCC 2007).

According to IPCC, vulnerability to climate change '*is the extent to which climate change may damage or harm a system; it is a function of both sensitivity to climate and the ability to adapt to new conditions'* (IPCC, 1996). As grassland systems and steppes dominate the landscape (Gupta et al., 2009) and as agriculture has already caused saline and devastated land (Ibrakhimov et al. 2007), the expected rise of temperature is a tremendous challenge for agricultural research, agricultural policy and farmers in the CAC region and also for macroeconomic policy in these eight states. Since many of the rivers in the region are trans-boundary, water supply problems have the potential to destabilize the political situation and social security (WBGU, 2007; see above).

Climate change predictions for CAC suggest that summers will be warmer and winters colder which limits cropping options (IPCC, 2007). Another big economic impact of climate change on the region – besides changes of biodiversity - will be through increased water scarcity. Irrigated crop production,

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[5] Annex I countries are obliged to reduce their emissions.

[6] Informing the UNECE-mission to Tashkent in April 2009 the Usbek government stated several times the decision, to increase the use of coal for energy production. This decision will be subject to the Environmental Performance Report Uzbekistan (UNECE), which is supposed to be published by the end of 2009.

which uses 83.6% of the water resources in the region (Abdullaev et al., 2006) will bear the brunt of this impact. In a similar manner, climate change would adversely impact the rangelands in Central Asia through significant decreases in forage biomass (Robinson et al., 2008) This is expected to directly decrease lamb production by 5-25% and wool production by 10-20% (ibid.).

Winter precipitation is likely to increase and summer precipitation to decrease in the region (ibid.), with increased frequency of very dry spring, summer and autumn seasons (Cruz et al., 2007). McCarthy et al. (2001) indicate that water resources in Central Asia are 'highly vulnerable' to climate change. Even though the annual water resources of the Syr Darya and Amu Darya basins are completely used up even now (Ososkova et al., 2000), most of irrigated areas in Central Asia are already facing high or very high water stress (Alcamo et al., 2003). If CO_2 levels double, the availability of water in the Syr Darya and Amu Darya rivers – the two major rivers in Central Asia - may decrease by as much as 30% and 40%, respectively (Robinson et al., 2008), leading to increased drought stresses and lower crop yields (Perelet, 2007). Agricultural irrigation demand in arid and semi-arid regions of Asia is estimated to grow by at least 10% for an increase in temperature of 1°C (Fischer et al., 2002). In addition, water diversions for non-agricultural uses are likely to increase, and over the long term, climate change will strongly reduce the overall water availability for crop production (McCarthy et al., 2001). The IPCC Fourth Assessment Report predicts that crop yields could decrease by up to 30% in Central Asia. Climate change is expected to exacerbate drought in Central Asia. Extended droughts can be ruinous for irrigated agriculture, farmers and pastoralists. In 2001, about half of the grain crops of Tajikistan failed because of drought (FAO, 2001). Likewise, in 2008, according to anecdotal evidence, in Tajikistan one third of the wheat area was not cropped due to the most extreme water scarcity experienced in the last 40 years.

In Central Asia, almost all of freshwater resources, in the form of river runoff, are derived from glaciers and permafrost (Hagg et al., 2007; Ososkova et al., 2000). Climate change is leading to glacier recession in the region (Bates et al., 2008). To illustrate, the glaciers Tian Shan and Pamir mountains, where most of Central Asia's glaciers are located, have retreated by some 25%-35% since 1930 (Yablokov, 2006; Kutuzov, 2005; Podrezov et al., 2001; Chub, 2000; also cf. Niederer et al., 2008; Perelet, 2008). WBGU expects that about 20 % of the glaciers in the Kyrgyz part of Tian Shan will disappear until 2050. WBGU assumes a shrink of glacier volume by around 32 % until 2050. As in summer about 75 % of the water in rivers originates directly in the glaciers, irrigation water in down-stream countries like Uzbekistan, Kazakhstan and Turkmenistan might decrease significantly in the middle of the century. Moreover the extension of hydropower in Kyrgyzstan and Tajikistan reduces water flow in summer. Although melting of glaciers could lead to extra runoff during many decades (Cruz et al., 2007; Hagg et al., 2007), this will increase the availability of water resources in the region mainly in early springs, while the run-offs in summer may actually decrease (Robinson et al., 2008). The runoff during warm and dry seasons is enhanced while glaciers are shrinking, but will dramatically drop after they have disappeared (Bates et al., 2007). In parts of Central Asia, climate change is expected to lead to increased incidences of floods and mudflows (Iafiazova, 1997). The short-time beneficial impacts of increased annual runoff will be also tempered by the negative effects of increased precipitation variability and seasonal runoff shifts on water supply and quality (Bates et al., 2007). This will pose serious threats to crop production during the vegetation period when there is very little precipitation in the region.

In Central Asia, close to 90% of the total annual water take off in the region is used in the agricultural sector for irrigation and leaching (Myagkov, 2006; Abdullaev et al., 2006). Most of the irrigated cropland in Central Asia is irrigated by highly wasteful surface irrigation (Bucknall et al., 2003). Besides, only 50-70% of irrigation water reaches the crops due to water loss in inter-farm and intra-farm irrigation pipes (Bekturova et al., 2007). This is high loss even if one assumes that technical losses occur in all irrigation systems and no 100% efficiency can be achieved. Excessive and inefficient water use, poor and insufficiently maintained irrigation and drainage network systems have led to severe land and water degradation in the region (Ibrakhimov, 2005; Conrad, 2007). Between 40%

and 60% of irrigated croplands in Central Asia are salt-affected and/or waterlogged (Qadir et al., 2008, Toderich et al., 2008). The current inefficient use of agricultural water coupled with the predicted population increases and the negative impacts of climate change on water availability will result in demand for water surpassing supply by far (even today, water resources of the Amu Darya for example are committed to 105%, due to drainage water re-use). Thus, climate change will multiply the current water stress, which already limits production in some areas and fuels tensions between the states. Hence, the development of new integrated water management strategies, including utilization of poor quality water is urgently needed (O'Hara, 2000; Toderich et al., 2008, Martius et al., 2009).

Agricultural production systems as agro-ecosystems

The rapidness of increasing day and night temperatures, growing unreliability of seasonal patterns (risk of frost or permanent rain at flowering for instance for cereals, vegetables and fruit trees) and increasing storms are a challenge for agricultural research. There is a tendency for research to tackle these challenges based on a philosophy of "management of ecosystems" and in an isolated, disciplinary way which we call the "linear approach" here. This thinking is strong in various cultures, which regard nature as subject to human interventions and needs . Also, in transition countries, science traditionally is highly atomized into disciplines (Gupta et al., 2009) and there has been little attempt at integrating them (Martius et al., 2004).

Agriculture is part of complex ecosystems with species relying on each other in a complex web of interactions. The systems approach to ecology suggests that it is in the links and interactions between the components of the system (the animals, plants and microorganisms and their innate, abiotic environment) where the system characteristics are fixed. One cannot grasp the functioning of a system by looking at its components alone without considering these interactions.

Furthermore, complex system behavior is difficult to predict, as innumerous possible parallel trajectories exist, specifically when the system is drawn over the boundaries, the "tipping point". This suggests that we are unable to predict the behavior of agroecosystems when these are facing drastic climate change, which may move organisms out of their reaction zone ("ecological niche"), trigger dramatic shifts in resource availability and other events, may they be catastrophic or of "creeping" nature (the latter making them more difficult to detect; e.g. Glantz 1999). This complexity has also been recognized in modern approaches to dryland management, e.g. the Dryland (or Dahlem) Development Paradigm (DDP; Reynolds et al. 2007), but these authors go one step further by considering the coupled human-environment system as the observation (and intervention) unit in which human action is part of the ecosystem.

Therefore, isolated, linear research on crops or climate change only (Asseng, et al., 2009) may fall short of addressing the complexity of the coupled system in the face of drastic climate change. Of course, there is urgent need for improving the quality of disciplinary science, e.g. breeding that addressed the heat and drought-tolerance of crops. But also, much more integrated research is needed. Rapidly increasing temperatures have significant impacts on the development of plant and animal communities in forests, meadows and fields. For instance "t*he loss of particular pollinator species (…) reduces the resilience of the ecosystem to change*" (FAO, 2008b). Food security relies on the ecosystem services of pollinators, specifically of bees *(Apis mellifera)* to a high degree. They are not necessary for rice, wheat and maize, but they are a precondition for or affecting an estimated 35% of the world's crop production, increasing outputs of 87 of the leading food crops (Collette, 2009). Pollination services cannot just be replaced by humans. Pollination by humans, tried for maracuja (*Passiflora edulis* forma *flavicarpa*) in Brasil resulted in extremely high costs, so that the fruits were not affordable anymore (Klein et al., 2006).

The worldwide economic value of the pollination service provided by bees and other insect pollinators was €153 billion in 2005 for the main crops that feed the world (Gallai et al., 2008). This is about 9.5% of the total value of the world agricultural food production. Gallai figures a loss of €50 billion for each, fruits and vegetable, and of €39 billion for edible oilseed crops (Gallai et. al., 2008). Also nuts, spices and stimulants (coffee, cocoa…) are affected in economic terms. Sukhdev estimates the value of bee pollination for coffee production at US$ 361 per hectare per year, although the benefits only accrue to producers within one kilometer of natural forests (Sukhdev, 2008, with reference to Ricketts et al., 2004). Gallai et al. underline that the average value of crops necessarily pollinated by insects was on average significantly higher than the value of crops, which do not demand pollination by insects, such as cereals or sugar cane (€760 and €150 per metric ton, respectively).

Worldwide there is a decline of pollinators (FAO, 2008b) due to diseases like the Varroa mite (*Varroa destructor*), climate change, invasive species, and modern agro-industrial production based on high input of chemicals and large fields lacking natural resorts for pollinators. Pollinators often are specialized on specific plants, for instance figs are pollinated by fig wesps only (*Blastophaga psenes*). Without fig wesps no figs. Gallai et al. (2008) estimated that pollinator disappearance would cause crop losses worth €190 to €310 billion. Therefore, pollinators have to be included in all agricultural research, specifically if it is focused on vegetables, fruits, oil seeds, nuts, stimulants, forage, herbs and medicinal plants. Habitats for pollinators have to be protected and re-established between the fields.

As the earliest fossil records of *Hymenoptera* are from the Middle Triassic of Central Asia (and from Austria; Hamm et al., 2009), research on biodiversity of bees and other pollinators would be desirable in Central Asia (see ABS below).

As beekeeping does not require a big plot of land, beekeeping components (including capacity-building and equipment) might be important interventions targeting those poorest sectors of society which have neither land nor animals.

Research on the effects of higher temperatures on beneficial soil organisms, invasive species, pests and pathogens is highly necessary; also simulations of future (agricultural) ecosystems, which include for instance the already changing seasonal cycles of birds and bird migration (Huntley et al., 2007). As birds eat insects, caterpillars and crops, these changes of birds' patterns may impact on agriculture. Agricultural and environmental research need to collaborate much closer. Research on the impacts of climate change on biodiversity and ecosystems and on the economics of ecosystems and biodiversity (Sukhdev, 2008) has only started and so far does not claim to be more than preliminary research.

The rare benefits of climate change are primarily in temperate zones, but also for some regions and crops the risk of frostbite might decrease and changes in the variety of crops might turn to the favorable. At higher altitudes an increase of temperature might prolong the potential growing season (Asseng, et al., 2009). But the risks and challenges caused by climate change prevail, specifically for the rainfed drylands in CAC, already facing severe heat and drought problems. The impacts of higher CO_2-concentrations or increased ozone concentrations on plant growth have to be studied. Globally IPCC expects an increase of CO_2-concentration of 1.9ppm year^{-1} (IPCC, 2007) up to 450 ppm in 2050[7]. CO_2-concentration of 450 ppm would lead to higher net photosynthesis rates, plant biomass production and transpiration use efficiency; decreased transpiration; higher canopy temperature and reduced crop nutrient concentration (IPCC, 2007). Under water-limiting conditions increased CO_2-concentrations have the highest impact (Asseng, et al., 2009).

As the impact of increased temperatures varies widely between crop species, specific regional figures for the CAC region would be needed, as already begun by Uzbekistan (SNC, 2009). For any prognosis

[7] Increase from pre-industrial concentration of 280 to 379 ppm in 2005, 450 ppm by 2050 (IPCC 2007).

of the impacts of climate change on food production and food security in CAC it is necessary to identify in which areas food and forage is and will be grown, for instance, now, in 2025 and 2050. Globally, about 50 % of total crop production originates from forest and mountain ecosystems, only 13 % from arable flat land, about 25 % from rainfed and irrigated agriculture in drylands and 12 % is rice produced in coastal ecosystems (FAO, 2008a). Research might identify promising sites in CAC and give advice to national governments, on which areas and crops they better focus their agricultural strategy. As global warming will specifically have negative impacts in dry and tropic regions, and specifically so for cereal crops (FAO, 2008a), the strong emphasis on wheat, but also rice and – to a much lesser extent - barley in Central Asia should be called into question. Legumes, potatoes or melons might be more favorable crops for the region in the future.

For the poor in rural areas, who often increase their income by collecting wild foods, higher temperatures and changing rainfall patterns are a significant threat: These wild plants, often neglected by agricultural research, might disappear altogether (FAO, 2008a)[8] should there be no efforts to support their adaption to higher temperatures or to those who lose their source of income. IPCC (2002) forecasts high losses of biodiversity on high altitudes in Asia/Central Asia. With view to ABS (see below), at least the focus on collecting and protecting ex-situ should be increased as an emergency plan, but more far-reaching action would probably be needed which warrants further strategic research on mountain agro-ecosystems.

Population growth and growing food demands

The world population, 6.8 billion in 2009, is expected to grow up to 9.1 billion in 2050. There are growing concerns that global food production will not keep pace with the growing needs, the more as also food consumption patterns change with growing wealth. This section looks at two aspects: can the CAC region feed itself with growing populations? And if yes, can it produce excess food that might urgently be needed in other regions, with even lower people-per-land ratios?

Whereas the population in the three Caucasus countries is supposed to slightly decrease until 2050 (from 15,9 million in 2008 to 15 million in 2050), the population in Central Asia still is growing fast, specifically in Uzbekistan, Tajikistan, Turkmenistan and Kyrgyzstan (all figures: UNFPA 2009 State of the world population annual report). In Central Asia, UNFPA expects a growth from 60.6 million in 2008 up to 79.9 million in 2050. Even more focused efforts to increase the productivity of germplasm cannot catch up with this high increase of food demand, as it is not reasonable to expect more than a 3-4 % productivity increase per year from breeding[9]. Therefore, food security has to be ensured by a range of measures which include changes in land use to high or at least more productive crops and varieties and improved agricultural techniques, the development of value chains and imports for instance of grain and rice. Land degradation, desertification and climate change as well as population growth will decrease the ratio of arable land per capita, which is already extremely low in most CAC countries except for Kazakhstan and Turkmenistan.

The two large neighbors of the CAC countries, China and India (40 % of the world population), are already net-importers of food. According to the Millennium Ecosystem Assessment (MA) there will

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[8] For instance in sub-Saharan Africa Levin and Pershing (2005) examined the favorite habitats of 5000 plant species. 81-97 % of these habitats will either decrease in size or shift due to climate change, by 2085 25-42 % of habitats will be lost (cited by FAO, 2008a).

[9] Dixon et al. (2009) write: "*Prior to the Green Revolution, the global average wheat yield was increasing at about 1.5% per annum: around 2.2% per annum in developed countries but less than 1% per annum in developing countries..; in the latter case, this was around one third of the population growth rate. The Green Revolution boosted the growth of average wheat yields to 3.6% per annum in developing countries during 1966-79. However, yield growth in developing countries slipped to 2.8% per annum during 1980-94, and then dropped to 1.1% per annum during 1995-2005..., once again falling below the population growth rate.*"

be a global rise in demand for food of 60–85 % by 2050, based on predicted population growth and assumptions about trends in consumption patterns (MA, 2005). FAO expects that the increase will be mainly reached by intensification, i.e. higher yields per hectare, more mixed cropping, and shorter fallow periods in developing countries and by using vast areas of potential land in Africa and South America. WBGU criticizes that these assessments take into account neither the effects of land degradation through soil erosion and deforestation nor the effects of climate change (WBGU 2007). Also Battisti et al. (2009) warn: *"With growing season temperatures in excess of the hottest years on record for many countries, the stress on crops and livestock will become global in character. It will be extremely difficult to balance food deficits in one part of the world with food surpluses in another, unless major adaptation investments are made soon to develop crop varieties that are tolerant to heat and heat-induced water stress and irrigation systems suitable for diverse agroecosystems"* (Battisti et al., 2009). To cope with the growing food demand, at least an additional 2,000 to 3,000 cubic kilometers of water (33% of current agricultural water use) are necessary for irrigated and rainfed cropping by 2030 (von Braun, 2008, with reference to Global Economic Symposium of The International Water Management Institute 2008).

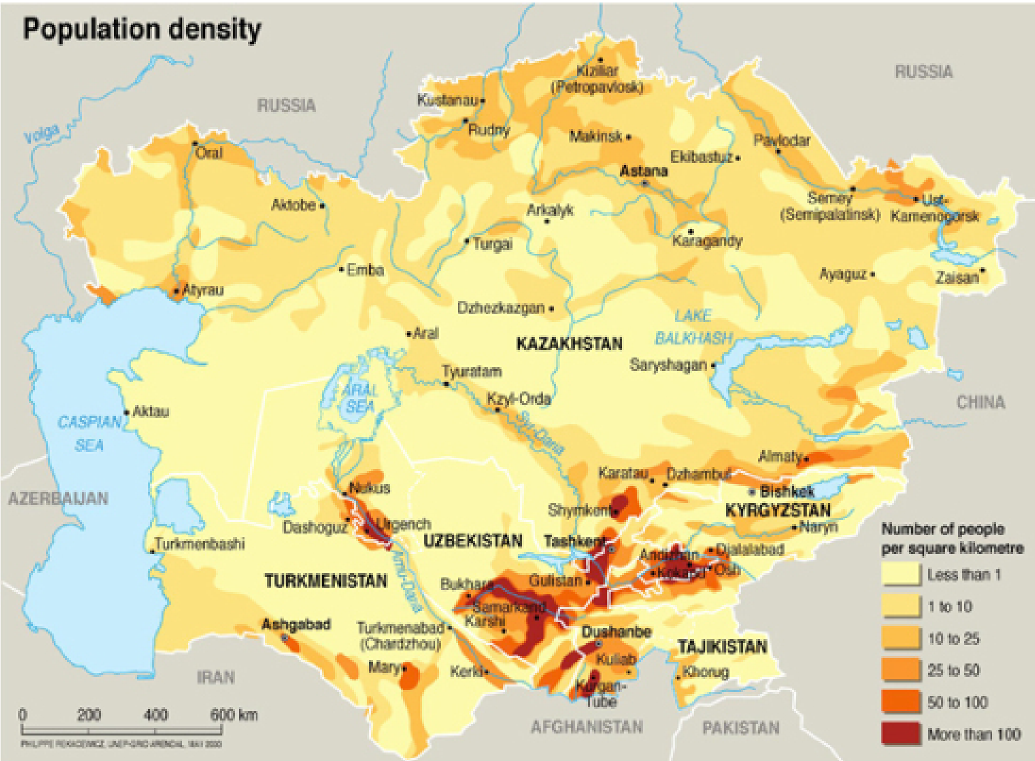
Climate change as a security risk

According to Welzel (2008), worldwide between 50 and 200 million refugees caused by environmental degradation and disasters are expected until 2050, and Hare (2005) even expects an increase of refugees caused by environmental degradation/disasters by 400-800 million until 2020. Refugees caused by environmental degradation and disasters are not yet regarded as refugees by the UN and therefore miss rights and assistance. Wars caused by water scarcity may make 2 billion people into refugees until 2050, according to Welzel (2008). The drying up of Aral Sea – an area of borders and of minerals – and trans-boundary rivers may fuel conflicts in Central Asia, too.

Welzel (2008) points out the vulnerability of countries where better educated groups from the middle class may become subject to the sentiment of being unfairly treated, and develop the capacity to destabilize society. Climate change gives a lot of room to this feeling to the young generation, to people in disadvantaged areas or ethnic groups. Welzel (2008) discusses that climate change is likely to cause social disasters and violence, as in areas with chronic or acute food insecurity and high ethnic diversity one group may be forced into migration. In CAC, many different ethnic groups and nationalities live close to each other. The Fergana valley is known for conflicts caused by environmental problems to have risen along ethnic borders (WBGU 2007).

Agriculture is one of the most important employers specifically in rural areas and therefore a factor of social stability in the CAC region. Although a high percentage of the population works in the agricultural sector, agricultural plays a less important role concerning GDP (see below). The low economic performance of the agricultural sector creates high social vulnerability: The percentage of young people (under 15) is high in Tajikistan (39 %), Uzbekistan (32 %), Turkmenistan (31 %) and Kyrgyzstan (30 %) (http://esa.un.org/unpp/). About 44 % of the population lives in rural areas in the Caucasus countries, and about 60 % in Central Asia. Therefore, specifically in Central Asia there are and will be numerous young women and men in rural areas who need to find a source of income. If agriculture is not able to provide jobs and income and if there are no other income resources, for instance by further processing the harvest, migration might increase, specifically migration of men (WBGU 2007). This will cause problems in their rural home areas and also in the urban areas they move into. Work migrants face more risks of HIV infection than residents (ILO, 2008). Work migration of men from remote areas is also one main reason for the spread of HIV into rural areas and thus additionally weakens the capacity of rural societies to adapt to climate change. Due to the global economic crisis the number of young men enabled to find a job in foreign countries might be limited (see below; "Tajikistan"). Migration from rural to urban areas might contribute to the challenge for the governments of the target countries of migration to ensure food security for those populations, hence, the food security problem is "exported".

Figure 1: Population density in Central Asia

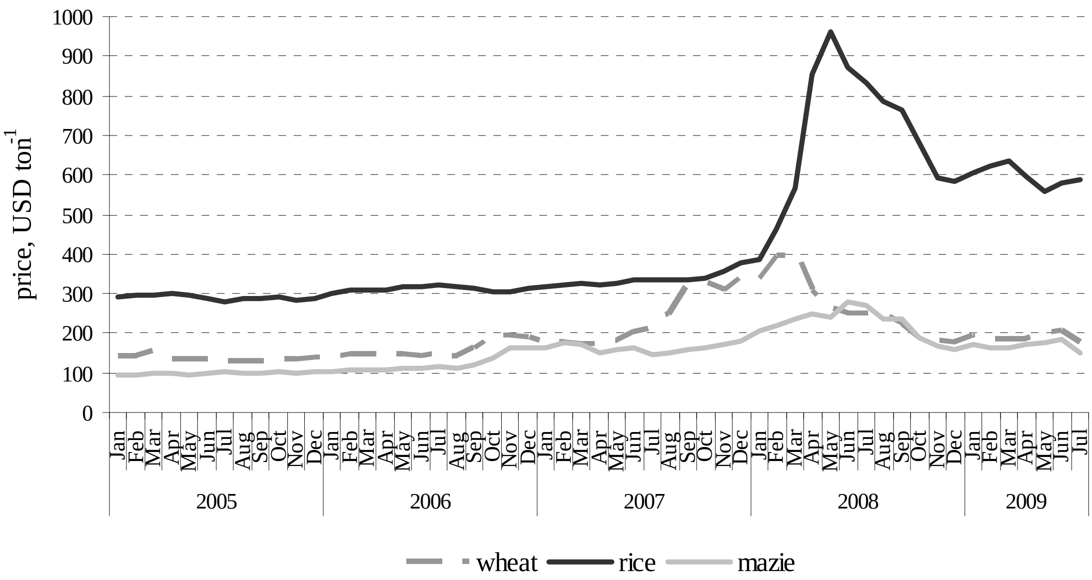


Cartographer/Designer Philippe Rekacewicz, UNEP/GRID-Arendal; http://maps.grida.no

Impact of volatile food prices on the CAC

International food prices had risen sharply between 2006 and 2008 (EBRD and FAO, 2008). Although they have fallen since then, they had been forecasted to remain high in the medium term (ibid.). The rising food prices have had an overall negative impact in the CAC countries, though the magnitude of the impact was different from country to country. Rising food prices have contributed to high food inflation in CAC countries. In fact, Kathuria (2008) indicates that the rise in food price accounted for by far the major proportion of the inflation in the low and medium income countries of the Commonwealth of Independent States (CIS), including the CAC region. The concurrent rise in some commodity prices as well as Government policies played a role in mitigating the adverse impact of rising food prices, but the impacts of rising food prices on the poorer parts of the region and the poorer strata of the population within the countries were quite important. Food spending represents the major share of their income expenditures. Alam (2008) indicates that the impact of rising food prices on poverty in the region could be significant – a 5% relative increase in food prices could increase poverty rates by 2-3 percentage points. Therefore, higher food prices posed challenges in terms of protecting the poor and vulnerable and providing with food security. To achieve these purposes, the countries of the region used domestic price controls and/or have banned or restricted food exports (Alam, 2008). Another policy method that the countries of the region used to mitigate the impact of food prices were social safety nets, which represented in monetary terms from 0.5-0.7% (Tajikistan, Kyrgyzstan) to 2.0-2.3% (Kazakhstan, Armenia) of the national Gross Domestic Products (Lindert, 2008), although with less than desirable targeting accuracy in most of the cases. Although, presently, the food prices have fallen to lower levels, the last crisis clearly demonstrated a high vulnerability of some of the countries in the CAC region to external food price shocks. High food prices in 2007 and 2008 increased governments' attention in Azerbaijan, Kyrgyzstan, Tajikistan, Uzbekistan and Turkmenistan once more to increase their production of cereals, particularly wheat.

Figure 2: International price of main agricultural commodities



Source: FAO, 2009. Wheat – US No.2, Soft Red Winter Wheat, US Gulf (Tuesday), Maize – US No.2, Yellow, U.S. Gulf (Friday), Rice –White Rice, Thai 100% B second grade, f.o.b. Bangkok (Wednesday)

Food prices in regions with high food insecurity also significantly divert from global market prices, e.g. in Tajikistan and Kyrgyzstan in April 2009: Although global food prices were about 24% below April 2008 levels, they were 8 and 9 % higher in Tajikistan and Kyrgyzstan, respectively (UNDP, CARRA, 2009b).

The borders erected after independence hinder trade within CAC. A *free market zone CAC* would provide several advantages: It would give room to better use the advantages of areas for special crops, for instance growing melons, fruits and vegetables in Uzbekistan, wheat and maize in Kazakhstan, and potatoes in the mountain areas of several countries. So, the quality of food might increase while prices may actually go down. A free market zone would create more options for marketing to farmers; transport would require less time and costs. Consumers would get better access to fresh and high quality food and more food variety. Thus number and amount of food insecurities might be decreased. And if they take place, they might be better managed.

According to WBGU (2007) and Pandya-Lorch (2000), worldwide food demand patterns are changing significantly towards meat consumption, specifically so in developing countries. However, only about one tenth of the cereal biomass fed to livestock is converted into meat (WBGU 2007). The lower the overall consumption of meat, the more effectively agricultural land and cereal yields can be spend for the benefit of human nutrition. But already now *"the bulk of world cereal production is used for the feeding of livestock"* (WBGU 2007). FAO estimates that well informed consumers might shift away from grainfed livestock (FAO, 2008). But these well informed consumers will remain a minority without further efforts. Food security is therefore also an issue of lifestyle that needs to be discussed with all relevant stakeholders, such as the education sector, the entertainment industry and global and national role models on the one hand and the fiscal sector on the other hand: If meat prices would reflect the real production costs including the "ecological footprint" (Rees, 1992; Wackernagel, 1994), consumption patterns might change back to more plant-based diets. As livestock is one of the main sources of greenhouse gases, a change of consumption patterns might create a win-win situation for food security and the mitigation of climate change.

Food independence versus improved integration into world market

Many international donors and banks suggest that "*nations should use their farmland to grow what's most profitable in world trade and use the proceeds to import food as needed*" (Moore Lappé 2008). Water deficits that cause a decrease in grain production are often seen as a cause of grain independence. Therefore, producing foods suited to the biophysical conditions is often seen as a way of avoiding virtual water exports (see below "virtual water").

The question, which strategy might be more favorable, has to be discussed also with view to increasing transportation prices due to energy prices and climate change policy. As the polluter pays principle started to be implemented also for carbon pollution under the umbrella of the Kyoto-process, long transport ways might become economically unfavorable within the next decades anyway. Lorry, flight and ship tolls will cause significant changes in global trade towards more regional marketing. At present also in Europe and Asia most of the food transports are done by train or truck. The CAC region is close to big producer and consumer markets like Europe, Russia, China and India, the later both representing 40 % of world population. Today, India and China are net importers for food. But reliable trade relations still have to be developed and international trade with new partners requires also more foreign languages skills.

Being landlocked, many of the countries of the CAC are adversely affected by rising transportation prices. Though energy commodities are a key source of exports for some of the countries in the region, higher energy and transportation costs affect agricultural producers even in those energy-rich countries negatively especially concerning external markets. Coletti et al. (2000) even observed that according to some experts, Kazakhstan, in spite of its huge potential for grain production, may have little future as a global grain producer partly because of high transportation costs. According to Molnar and Ojala (2003), transportation costs in the region may reach as high as 50% of the value of the goods, if to be exported to global markets. Potato, as a more regionally traded commodity, might therefore contribute to food security and income for the farmers in a more reliable way than some other crops.

High transportation costs can be also an important barrier for the intra-regional trade (Luong, 2003), which adversely affects the food security of food-deficient countries in the region, making it expensive for them to import food products to supplement their lacking internal production. On the other hand, high transportation costs are also making it difficult for smallholder rural producers in the region to access urban markets, where their produce can fetch higher prices (World Bank, 2005). High transportation costs increase food prices also for urban families.

Due to CGIAR-experience high transportation costs could also make it difficult to spread agricultural technologies. For example in southern Kazakhstan, application of phosphogypsum could be an effective remedy against the problem of magnesium-rich soils, allowing the increase of crop yields by as much as two-three times. However, there is a lack of adoption among farmers, since they are not able to overcome high transportation costs of phosphogypsum from the fertilizer factory dumps 300 kilometers away from their fields (Aw-Hassan et al., submitted).

Therefore, upgrade and development of transportation infrastructure in the region should become one of the intervention areas of the governments and the international development partners in the region in order to facilitate regional trade, food security and sustainable agricultural development. Due to climate change and carbon taxes on transport emissions railway-systems (where possible) might be better than motorways for long distances. Increasing transportation prices are also an argument to shift agriculture towards high valuable crops such as fruits, vegetables, pharmaceutical herbs, labeled organic food and towards value chains for instance for cotton, wool, fur and silk. But vegetable and fruits require much better storage and transport facilities and know-how, specifically with view to raising temperatures.

Two recent studies (Kohlschmitt et al. 2007; Bedoshvili et a. 2009; below "Underutilized Plants"), examine the possibilities of introducing alternative food and non-food crops in Central Asia and the Caucasus, using the more vulnerable regions of Khorezm (Uzbekistan, downstream in the Aral Sea basin where food security is threatened by water availability) and West Georgia (a sub-tropic area where crops were produced for export to the Soviet Union in former times, a market which has become totally obsolete after independence). This represents one possibility to initiate diversification in the crop portfolio of farmers of those regions, make them less dependent on world market fluctuations of single crops and their products, and allow for better resource management if crops are carefully chosen to match the regions conditions. These studies then also address sales opportunities and risks of those crops on the European Market, as one alternative for the generation of foreign earnings.

But quality and standard control is not reliable yet, which hampers for instance export to Europe. CAC also cannot yet benefit from the growing demand for organic food in Europe. At present Europe imports organic food from Chile, South Africa, China and other areas, while farmers in CAC, a much closer area of production, did not yet start the process of certification. Specifically in Armenia and Georgia there are requests to get assistance in the process of labeling. These should be assisted by the CGIAR.

Whether it is favorable to shift towards higher world market integration depends on the product, the region, the GDP in general and on the probable figures of arable land per capita within a few decades. The lower the rate of arable land per capita the higher the need to grow high income crops and to develop value chains. Countries with high GDP due to high income by mining, industry or services (Kazakhstan, Turkmenistan, Uzbekistan and Azerbaijan) are less affected by high global food prices than poor countries like Tajikistan, Kyrgyzstan, Georgia or Armenia. Georgia and Armenia are geographically and culturally much closer to the European market. But though: With view to the ups and downs of global food prices and the fact that many areas are remote and difficult to access, at least for Tajikistan and Kyrgyzstan and the mountain areas in Georgia and Armenia it seems to be favorable to follow the argument of Wehrheim et al. (2003): "*While subsistence farming is often said to be a vicious cycle of the transition process, one of its most obvious benefits is its role as a buffer against food insecurity. In fact, in those regions where poverty is likely to persist in the medium run, support for subsistence farming might have the potential to reduce food insecurity substantially*."

High transport prices will also have effects on food help in cases of urgent food insecurity, specifically in remote mountain regions: "*With one ton of humanitarian wheat shipped to GBAO*[10] *costing from $250 (that purchased in Kazakhstan and shipped to Khorog) to $700 (that purchased in the US and shipped by boat, then train, then truck to Khorog), it was clear that such an expensive programme would not be sustained long. Thus, even with imports of seed and fertilizer, the costs of locally produced wheat in the valleys of Gorno-Badakhshan were estimated to be only $65 to 70 per ton in the late 1990s (MSDSP documents)."* (Nygaard et al., 2005) With ongoing climate change in mountainous regions the increase of storms, floods and landslides will damage or totally destroy the transport and distribution infrastructure more often than already nowadays. Also with view to these foreseeable disruptions of food supply chains food sufficiency seems to remain a necessary strategy in remote areas.

"*Surely today's deepening hunger crisis reveals the dangers of vulnerability to policies completely outside [a countries'] control. The end of hunger and real food security require provisioning from domestic resources wherever possible. This approach, combined with a solid international grain*

[10] Remote mountainous area in Tajikistan with high food insecurity and high dependency on food aid in the early 90ies.

reserve to be released in response to unforeseeable setbacks, has the best chance of assuring adequate food supplies" (Moore Lappé, 2008).

Biodiversity of agroplants und plant genetic resources management

The great richness in genetic resources is the result of evolution processes taking place in diverse physical and climatic conditions. The CAC Region encompasses two of eight Vavilov's major centers of crop origin. The wide altitudinal variation and climate zones in CAC coupled with the long tradition of trade along the Silk Road favored biodiversity of crops. CAC countries are extraordinary rich in crop wild relatives, landraces and different breeding varieties of cultivated plants. Wild ancestors of many of world's commodity crops (cereals, pulses, vegetables and fruit species) are still growing in nature. This offers a rich pool of gene resources for utilization in agriculture at present and in the future. Among those crops originated within the Irano-Turanian Flora, are the wild relatives of cereals (s.a. wheat, barley, secale), legumes (s.a. lentils, chickpea, faba bean, pea), forage (medics, *Trigonella, Trifolium, Vicia, Lathyrus*), vegetables (s.a. cabbage, red beet, onion, garlic, carrot, melons), fruit trees (s.a. almond, apricot, apple, pear, pistachio, cherry, plums, walnut, pomegranate, quince, hazelnuts, azarole, cornelian cherry, Russian olive, grape, fig, chestnut, mulberry), industrial crops (s.a. safflower, flax, cotton), and countless medicinal and aromatic plants (s.a. *Mandragora, Achillea, Glycyrrhiza, Valeriana, Ferula*). Many of the wild fruit trees form unique natural forests, important for both ecological and socio economic reasons. From the wild, these species have been domesticated and selected by local populations who have patiently developed thousands of valuable varieties, highly adapted to a broad range of climatic conditions. The great diversity in domesticated animal breeds and varieties is also the result of the remarkably high human and cultural diversity that is present throughout the region.

More than 8,100 plant species are recorded from the region, of which are 890 endemic.

Table 1: Number of plant species and percentage of endemism in the CAC countries

Country	Number of plant species	Endemism (%)
Armenia	3,555	3
Azerbaijan	4,500	5
Georgia	5,000	21
Kazakhstan	6,000	14
Kyrgyzstan	3,786	5
Tajikistan	5,000	20
Turkmenistan	2,600	18
Uzbekistan	4,800	8

Source: Bioversity International, Agrobiodiversity in Central Asia and the Caucasus (unpublished)

The flora of CAC countries hosts a very high number of most common wild relatives. These wild species play a very strategic role in crop improvement programs as potential source of resistance to biotic (pest and disease) and abiotic factors (drought, frost, salinity, etc.)[11]. The region is also known for its wealth in domesticated animal diversity, particularly with regard to small ruminants (Iniguez and Mueller, 2008).

[11] For further information on occurrence of progenitors of cultivated species within the CAC/Near East Center of Crop Diversity (Zhukovsky 1985): focus on Armenia, Azerbaijan, Georgia and Turkmenistan see Annex 1 and on occurrence of progenitors of cultivated species within the CAC/Central Asian Center of Crop Diversity (Zhukovsky 1985): focus on Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan see Annex 2.

The high value of these varieties can be assessed in terms of their peculiar economic traits including taste and flavor (as in the case of the melons famous for their sweetness), appearance, storability and shelf life (for instance apples, pomegranates, melons, pears, grapes are available all year round at local markets), adaptation to drought (particularly in pistachio and pear), good quality of dried fruits (raisins, apricot, and plum). The higher the number of varieties, the better the chances to adapt agriculture to climate change.

The CAC-countries maintain germplasm holdings in genebanks and also *in situ* reserves, agro-ecosystems and protected natural ecosystems. They do research, collect and provide information and trainings, but genetic erosion and reduction in population goes on. A lack of knowledge is obvious on all levels. Lack of awareness, growing human pressure, climate change, environmental disturbances and related factors put pressure on biodiversity.

In the CAC, the development of comprehensive national plans for the preservation of plant genetic resources for food and agriculture (PGRFA) is highly desirable, including *in situ* and *ex situ* activities. Knowledge should be shared in more efficient ways. Capacity building is needed. Strategic approaches should link conservation and use and require the establishment of a sufficiently authorized institution like a National Plant Genetic Resources Advisory Council. The fields of priority identified in the national strategies for management and use of Plant Genetic Resources in Armenia and Georgia (McGuire 2009; Qualset 2009) can be generalized for all CAC countries: The national governments are in charge to establish integrated plant variety protection system by national rules and legislations. Efficient conservation requires long-term facilities for maintaining ex situ collections, field genebanks for perennial crops and in vitro storage for vegetatively propagated crops. *In situ* conservation has to be managed and monitored, adequate PGRFA documentation is necessary. Collaboration of PGR collection holders and farmers has to be improved and farmers should become actively involved in conservation of PGRFA. To establish and to meet national plant breeding targets breeding programs, public and private sector partnership opportunities and also to increase resources and institutional capacities should be planned. Communication between plant breeders and seed producers might intensified by networks or associations. Effective PGRFA requires also educational and public awareness programs to avoid destructive measures, traditions, behavior – behavior on purpose or out of ignorance. Capacity building might include training in research and development, study tours, to secure funding for more staff positions on all aspects of PGRFA management, state of the art-equipment and facilities for conservation and use of PGRFA, international exposure and exchange programs and others.

Since the collapse of Soviet Union there is a lack of coordinated and integrated approaches to sustainable use of natural resources. Therefore, the Central Asian Network on Plant Genetic Resources (CAN-PGR) was established by Bioversity International in 1996 with the purpose to coordinate activities on plant diversity conservation and use through collaborative research on set regional priorities, exchange of information and germplasm, and regional training. In 1999, the three Transcaucasian countries (Azerbaijan, Armenia and Georgia) joined the Network and it was renamed into Central Asian and Transcaucasian Network on PGR (CATCN-PGR). Along Eight Regional Crop Working Groups have been established in the framework of this regional cooperative mechanism and each country is responsible for the coordination of the activities of certain working group at regional level: cereals and grain legumes; fodder crops; fruit and berries, subtropical plants and grape; vegetables and melons; industrial crops; wild (edible), medical and aromatic crops; forest plants and species; cotton. A number of collaborative activities in the area of PGR collecting, assessment of distribution, characterization (vegetables, pistachio, pomegranate, melons, etc.), documenting (establishment of computerized dbase on forest, fruit, cotton genetic resources) and capacity building are undertaken by the Network at the regional, national and international levels.

For all kind of crops, cereals, potatoes, vegetables, fruits, fodder crops, also seed production and seed distribution needs improvement. Also for seed production and seed distribution targets are useful and completion among the oblasts. Poor farmers have to benefit from better seed as well, even if they cannot afford to pay more. The importance of biodiversity, seed production and seed distribution for food security might be underlined in the public. Also the output of trainings should be measured. Who for instance takes part in the trainings – preferably multipliers from different villages.

CAC agricultural research in the global context

The collapse of the Soviet Union has had considerable impact on agricultural research in CAC. National research systems, previously staffed by highly qualified scientists were dilapidated, are now notoriously underfunded (on average the governments in CAC invest less than 0.1 % of GDP to agricultural research), in want of qualified staff that left for better remunerated positions, and without any bold strategies for staff rejuvenation. Centralized decision-making stifles initiative. Unfamiliarity with the culture of proposal writing for securing your research portfolio is another barrier. Lack of contact with the international scientific community and English language deficiencies have deprived scientist of the benefits of international public goods. The level of coordination and the linkages within and between national agricultural research systems (NARS) are low. Furthermore, the former channels of knowledge dissemination have broken down but no functional extensions systems have been put in place. Quality control labs for water, soils and crops need to be upgraded, technically and with regard to norms and procedures. But CAC countries still hold also agricultural research sites, which deliver high standard research.

A recent survey assessed the priorities in agricultural information and communication in Kyrgyzstan in a pilot study that has exemplary character for the whole region (Mirzabaev et al., 2009). Major findings are that collaboration among institutions that are responsible for agricultural research and those that deal with development is not effective; that the agricultural research and education systems appear to be largely disconnected from the needs of farmers, extension organizations, cooperatives, or the budding private sector; that, while the ICT sector is developing fast in the country, ICT infrastructure development remains problematic, above all internet access especially in rural areas. The lack of specialized publications remains another problem, particularly with regard to more farmer-oriented publications in Kyrgyz language. State organizations in the agricultural sector are often badly equipped, underfunded, and remains isolated from the international scientific community.

The mandate of the CGIAR: Agricultural research for the poor in CAC

"*It is the poor who lose the most, whatever the nature of the crisis"* is (von Braun, 2008). Generally, agricultural research works for the benefit of agricultural households – those which own either land or animals. But very poor households in rural areas often have neither land nor animals. These are often permanently female-headed households without income from abroad or descendents of late immigrants. In rural areas these households usually live on day labor and harvesting of wild plants, chopping firewood for others etc. If not being paid in kind, they have to purchase all food on the market. In remote mountain areas often the food prices are double or triple as high as in the lowlands due to high costs for transport (see "Tajikistan"). Any crisis hurts them severely – high food prices, droughts and in consequence less day labor on the fields, lower chances to sell wood, fodder etc. Poor people spend 50 to 70 percent of their income on food and are highly vulnerable to rising food prices and decreasing income by day labor. "*To cope, households limit their food consumption, shift to even less-balanced diets, and spend less on other goods and services that are essential for their health and welfare, such as clean water, sanitation, education, and health care*" (von Braun, 2008). Children of these (permanently female headed) families often cannot attend school (regularly), specifically girls, because they have to contribute to the family's income or take over the domestic work, when the mothers work on day-labor.

A large body of smallholder and subsistence farming households in the dryland tropics is highly exposed to climate change related crop failure and increased diseases and mortality of livestock (Easterling et al., 2007). The more these poorest of the rural poor increase in number, the cheaper day labor will be. The increased frequency of climate extremes and disasters reduces the time for poor households to recover from one climatic shock to another (DFID 03, 2004). This is particularly so in mountainous regions, which are highly exposed to global warming and to disasters such as erosion and landslides. Poor households often have marginal land in areas more exposed to drought and natural disasters; global warming increases the risk of losing the few assets they have and then – lacking savings – they will either stay as Man/Woman of Nothing living on day-labor, or be forced into migration.

On the other hand, various regions characterized by subsistence and smallholder agriculture are "*storehouses of unexplored biodiversity*" (Easterling, 2007). Pressure to cultivate marginal land or to adopt unsustainable cultivation practices as yields drop might endanger biodiversity of both wild and domestic species (Easterling, 2007). The poorest without land and animals can barely be figured in numbers due to insufficient data, but with view to both, human rights and biodiversity, they should become a special target group for CGIAR-activities. As CGIAR has the mandate to contribute to the improvement of living conditions of the poor by agricultural research, all research projects should include components for the benefit of the growing number of the poorest of the poor, living in agricultural areas but having neither land nor animals.

Food security in times of climate change has to be seen gender related specifically in this issue: If agriculture is not profitable anymore, specifically men migrate for work – but not all of them transfer cash to their families. Already now in the mountain regions in CAC there is a drain of male manpower, leaving women, children and old aged inhabitants within a more and more fragile environment and often less income. These groups – occasionally and permanently female-headed households and families without any property – will increase as climate change goes on and more research on income generating activities within or related to agriculture is needed. IAASTD recommends investment in research to increase "*the sustainable productivity of major subsistence foods including orphan and underutilized crops, which are often grown or consumed by poor people. Investments could also be targeted for institutional change and policies that can improve access of poor people to food, land, water, seeds, germplasm and improved technologies*" (IAASTD 2009a).

The review on the UN-decade of mountain partnerships in CSD 2012/13 represents a chance for NARS- and CGIAR-led research in CAC to give inputs, to advocate for agricultural research in this field and to raise awareness for conservation of sites where underutilized plants grow.

Gender issues require more attention

Gender should become a more important issue within agricultural research not only with view to poverty and migration of men, but also concerning decision-making on all levels. Under the Project "Integrated Water Resources Management in Fergana Valley" (IWRM-Fergana, 2001-2010, Uzbekistan, Tajikistan, Kyrgyzstan) social surveys were conducted in the project area to get first-hand information about the socio-economic constraints and role of women in water management. The results show that the number of women leading agricultural production and number of women workers in agricultural fields have increased significantly over the last decade, and that women are now playing a very crucial role in the development of irrigated agriculture in the region. Thus, equal access of men and women in the decision-making of water resources management is required - however, in the main departments and operational services of water, men still dominate. It is interesting to note that in the institutions situated in the capitals, women participation is more visible than men, while at district level their participation does not exceed 25% of the total number of employees. Generally, women participation is only about 18%.

Women generally work in the field at wages of about 15-20$ per month or they are paid in kind, e.g. receiving a share from the agricultural production. According to the IWRM research, payments are made only during the harvest season. Mostly women do the labor-consuming manual field work, while men basically do more qualified work – carrying out the irrigation, application of fertilizers, plowing and cultivation.

Over the last decade, almost in all regions of Fergana valley, the number of women who play key roles in all spheres of agricultural production has increased significantly, while their contributions are not fully recognized. This is mainly due to the fact that most of the men have left their homes in search of employment in other cities and countries and women have no choice but to play this role.

In Tajikistan members of dehqan farms are basically women, while the head of a dehqan farm typically is a man. Women have no rights in such dehqan farms. They have no information about incomes, expenses on the land and production. Women are reluctant to take control of land or share of the land in dehqan farm because they might not be able to get any profits due to uncertainty of irrigation water supply. As women they often cannot equally participate in the management of the canal or district water management and are often the last in the chain to get water.

In Uzbekistan the situation is different, as here the number of women heading a farm is increasing. The basic problem in agriculture and in housekeeping is water. Often the lands of women-farmers are located in dry zones and on marginal land due to different reasons. Often there is no water on their lands and even when they water is allocated to them, it is in small volumes and for short periods. However, due to collective actions it has become possible for them to receive water and to gain knowledge in the discipline of water use. Women-farmers indicated that they have significant difficulties with administration due to lack of economic and legal knowledge. As water is the crucial factor in their work, farmers should have good knowledge of water planning, on water distribution, rates and duration of irrigation.

It became clear from stakeholder meetings held in the Osh region of Kyrgyzstan, in the Fergana and Andizhan regions of Uzbekistan and in Sogd region of Tajikistan, that the problems encountered were common to all these countries. The basic problem is related to low profitability of agricultural production and absence of alternative job opportunities for both men and for women. Due to gender patterns in CAC the women stay with children, elders and farms, whereas men migrate. If the migrants are ready and able to support their family in the village, the living standard of these temporarily female headed households may even rise (WFP, 2008). Nevertheless, socially these economically forced separations are not desirable for all members of the families. As the women often cannot take over the full part of mens' work additionally to their own, agricultural infrastructure (like terraces) often slowly degrades. In the villages whose populations are diminished from migration, there is also often not enough workforce to do additional work to adjust agriculture for climate change mitigation and adaptation.

Therefore, agricultural research is challenged to make agriculture more profitable even on marginal land and to advocate for the development of job-creating value chains in order to avoid migration of men. Parallel agricultural research has to adjust its performance to the needs of women-farmers. They have different time schedules, they are often interested in growing other crops than men and they need different technical equipment, which is not so heavy. The fact of an increasing number of women-farmers might be a chance to speed up the change towards fruits, vegetables and further processing of the harvest. Research on market chains therefore is necessary to map out a development strategy for women-farmers.

3. The great disparity within the CAC

The economic situation in CAC

The rise in Central Asia's food insecurity is an indirect result of a poor macroeconomic environment (Rhoe et al. 2008). All eight countries are still in the process of transforming agriculture into the past-soviet-context of market-oriented production. Nevertheless, almost two decades after independence, the economic situations in the eight countries in CAC differ considerably.

Figure 3: Economic Indicators of CAC countries

		Armenia	Azerbaijan	Georgia	Kazakhstan	Kyrgyzstan	Turkmenistan	Uzbekistan	Tajikistan
GDP (purchasing power parity): (billion USD) (2008 est.)		$18.92 (2008 est.)	73.65 (2008 est.)	$21.6 (2008 est.)	$176.9	$11.41	$29.65 (2008 est.)	$71.63 (2008 est.)	$15.4 (2008 est.)
country comparison to the world:		125	76	117	57	144	106	78	133
GDP Per capita									
GDP - per capita (PPP - 2008):		$6,400 (2008 est.)	$9,000 (2008 est.)	$4,700 (2008 est.)	$11,500	$2,100 (2008 est.)	$6,100 (2008 est.)	$2,600 (2008 est.)	$2.100 (2008 est.)
country comparison to the world:		128	109	145	96	184	130	171	187
GDP - composition by sector:	Agriculture	17.2%	6%	12.8%	5.8%	32.4%	10.7%	28.2%	23%
	Industry	36.4%	62.6%	28.4%	39.4%	18.6%	38.8%	33.9%	29.4%
	Services	46.4% (2007 est.)	31.4% (2008 est.)	58.8% (2008 est.)	54.7% (2008 est.)	49% (2008 est.)	50.4% (2008 est.)	37.9% (2008 est.)	47.6% (2008 est.)
Labor force:		1.2 million (2007 est.)	5.782 million (2008 est.)	2.02 million (2007 est.)	8.358 million (2008 est.)	2.7 million (2000)	2.089 million (2004 est.)	15.28 million (2008 est.)	2.1 million (2008)
Labor force - by occupation:	agriculture:	46.2%	39.3%	55.6%	31.5%	48%	48.2%	44%	67.2%
	industry:	15.6%	12.1%	8.9%	18.4%	12.5%	14%	20%	7.5%
	services:	38.2% (2006 est.)	48.6% (2005)	35.5% (2006 est.)	50% (2005 est.)	39,5% (2005 est.)	37.8% (2004 est.)	36% (1995)	25.3% (2000 est.)
Unemployment rate:		7.1% (2007 est.)	0.8% (2008 est.)	13.6% (2006 est.)	6.9% (2008 est.)	18% (2004 est.)	60% (2004 est.)	0.9% (2008 est.)	2.3% (2008 est.)
Population below poverty line:		26.5% (2006 est.)	24% (2005 est.)	31% (2006)	13.8% (2007)	40% (2004 est.)	30% (2004 est.)	33% (2004 est.)	60 % (2007 est.)

Source: CIA Factbook

GDP in CAC originates mainly by industry and services, though agriculture plays a vital role in society. GDP per capita ranges from 11.500 $ (Kazakhstan) to 2.100 $ (Kyrgyzstan and Tajikistan). Tajikistan and Kyrgyzstan are among the poorest countries worldwide, whereas Kazakhstan is in the middle range. While Turkmenistan, Uzbekistan and Kazakhstan overexploit Syr Darya, Amu Darya and other water resources for agricultural purposes, they do it for extremely low economic benefit (agricultural share of GDP: 10,7% in Turkmenistan, 28,2 % in Uzbekistan and 5,8 % in Kazakhstan). Like Kazakhstan, Azerbaijan derives only 6 % of GDP from agriculture. In conclusion, the environment in the CAC region pays an extremely high price for low agricultural income.

But agriculture is still an important asset for stability, as still a high share of labor force is occupied in this sector: 31.5 % in Kazakhstan, 44 % in Uzbekistan, 48.2 % in Turkmenistan, 55.6% in Georgia and 67.2% in Tajikistan (global average: 36 %, FAO, 2008).

Specifically concerning Turkmenistan, Uzbekistan, Kazakhstan and Azerbaijan, these figures should highly determine the point of view and the strategy for any advocacy towards sustainable agriculture: Labor, risks and conflicts in the course of climate change, environmental degradation, migration and social stability seem to be promising arguments.

After gaining their independence, CAC countries - except Kazakhstan - increased the area under wheat, the main staple in the region, at the expense of other crops to obtain grain self sufficiency (Olimjanov et. al., 2006). This has had by far the largest effect on crop diversification and changes in crop production. Due to the loss of its traditional market outlets, Kazakhstan first reduced the area under cereals, but then increased its area under wheat by more than 1 million hectares (Mha), to ca. 13.2 Mha in 2008, fuelled by the increase of the world market prices of this staple (FAO, 2008).

The three Caucasian countries plus Kazakhstan and Kyrgyzstan early on embarked on market–oriented and in part diversified production systems. Turkmenistan, Uzbekistan and Tajikistan maintained the state regulated production systems in particular for cotton and wheat (cf. Wehrheim & Martius 2008); however, in 2009 Tajikistan started to release the state order on crops.

The growing uncertainty of agricultural commodity prices from the recent years has increased the risk of agricultural producers as well as creating challenges of obtaining food security. A common market might work as a buffer for all. A wide-scale introduction of market reforms is conducive for an effective allocation and use of resources. Therefore, economic policy and institutional reforms should aim at increasing the role of private involvement and to lower transaction costs in doing business whilst liberalizing external trade and internal trade reforms must be geared towards income gains for the CAC countries while benefiting farmers and rural poor people. Experiences showed that a gradual introduction of market reforms is often preferred as this would allow input and output markets to respond to the different speed of price responses.

Besides over utilizing the environment and climate change, there are three main issues: First, most of the CAC-countries produce only agricultural raw materials like cotton, wheat, rice, potatoes, legumes, fruits, vegetable, fruits, meat, fur and wool (Karakul sheep), but – except Georgia (wine) – don not further process significant parts of their harvest yet. Second, although high biodiversity offers good options in the CAC region, organic farming is not yet a topic – except in Armenia and Georgia, which need assistance concerning certification and marketing. And third, exchange of agricultural goods within CAC and abroad is still underdeveloped.

Environmental and agro-ecosystemary conditions for food production in CAC

Although about 70 % (of 410 million hectares) are classified as agricultural land, mountains, deserts and steppes prevail and restrict agricultural land use. 88 % of the land is used as permanent pastures, 7 % arable rainfed and only 5 % arable irrigated (FAO, 2006).

Soil conditions heightening the risk of land degradation in the whole Central Asian region include salinity, sodicity, hydromorphy, soil shallowness, and risk of erosion (FAO, 2000). Among these, soil salinity, sodicity and waterlogging are the most severe affecting 53% of the countries arable lands; 50% in Uzbekistan, 96% in Turkmenistan, 16% in Tajikistan, 12% in Kyrgyzstan, and more than 33% in Kazakhstan (Bucknall et al., 2003). Bucknall et al. also report that approximately 600.000 ha of irrigated cropland in Central Asia has become derelict over the last decade due to water logging and salinization. It is estimated that in Uzbekistan alone approximately 20.000 hectares of irrigated land is lost to salinity and invariably abandoned every year. Huge amounts of productive irrigated lands are turning to degraded marginal lands, which are then abandoned by farmers (Toderich et al., 2009). Giese and Sehring (2007) estimate that in the Fergana valley, the most productive agricultural area in CAC region, 84 % of irrigated land is meantime degraded by high salinity. In the last decades, the area affected by secondary salinization increased rapidly in Karakalpakstan, Khorezm and Syr Darya regions (Mirzachuli steppe) in Uzbekistan), northern Turkmenistan (Dashauz province), Kyzylorda region in Kazakhstan, Fergana Valley and Asht massive along Syr Darya river both from Tajik and Uzbek trans-boundary areas; Kashkadarya, Chardjoy and Bukhara oasis along Amu-Darya river. In saline areas capita incomes are 30% lower than average national indicators and unemployment levels 40% higher.

The highly productive livestock system has deteriorated and livelihoods of the people have dramatically declined. It was estimated that areas of rangelands seriously affected by salinity in Kyzylkum desert cover about 2.8 mln ha (UNDP Report, 2007). About 1.24 mln hectares of rangelands, located in the vicinity of Aydarkul-Arnasay Lake Systems (AALS) are subject to serious degradation due to the salinity and overgrazing resulting in a dramatic decline in annual productivity of crops and rangeland systems (Wahyuni et al., 2009). Accumulation and migration of salts throughout soil profiles in these areas led to an irreversible degradation of vegetation and decreasing of botanic diversity of main plant communities. The virgin psammo- and xerophytic desert plant communities were replaced by halophytes (salt loving plants). Such a phenomenon induced the eradication of useful, endemic or rare desert plant species and to the reduction of rangelands productivity (Toderich et al, 2008, 2009). Fodder areas due to severe land degradation, including loss of soil fertility and secondary salinization, declined by 9-14% (ADB Report 2007, Lamers et al., forthcoming).

Semi-arid climate, low amounts of precipitation, desertification and salinity do not allow extending the area of irrigated land, specifically as long as agricultural methods do not respect the ecological resilience of ecosystems. Climate change ultimately demands not only to work along short-term (20 years) sustainability of agricultural practices, but the preservation of ecosystem services, which offer tremendous values for the well-being of people and economy as well.

To show the spectrum of variety within CAC region, three countries are presented in short profiles: Uzbekistan is one of the better-off-countries in the region, population figures are high and agriculture is mainly focused on cotton and wheat, pastoralism on Karakul sheep. Uzbekistan is a net-exporter of food. Tajikistan is – as Kyrgyzstan – one of the very poor mountainous countries and highly dependent on food imports, often even on food aid. Georgia has been chosen among the three countries in Caucasus, because of its biodiversity and because it does not only produce grapes, but developed also a value chain for grapes/wine.

Uzbekistan – economy, climate change and agriculture

In Uzbekistan even economically, agriculture is still a key sector contributing to GDP by 28.2 % (2008). The Uzbek agriculture produces 80 % of the entire food consumption in Uzbekistan.

Socially, agriculture is the most relevant sector in Uzbekistan. The Uzbek population increased rapidly from 8.4 mln in 1960 to 26.7 mln in 2007 (the current population growth rate is 1.732 %), and the prognosis for 2020 is about 31 mln (http://esa.un.org/unpp). Already now, the arable land per capita (0.18 ha per capita) is below the global average (0.26 ha per capita). Some 64.1 % (2007) of the total Uzbek population live in rural areas. 63 % of the rural population makes their living on agriculture. 88 % of the Uzbek population lives under desertification risk, which will increase due to climate change. 32.4 % of the Uzbek population is younger than 14 years, so there will be a high potential for migration to urban areas in case of rapidly decreasing income in the agricultural sector. In Uzbekistan, which exceeds the other countries in number of population, the urban areas are already densely populated. Also in order to prevent migration from the land and social frictions within society, it would be desirable to give higher priority to sustainable development in the agricultural sector in Uzbekistan.

Uzbekistan is highly vulnerable in times of climate change, as water supply for irrigation depends to 90% on trans-boundary rivers. The run-off patterns are likely to change as to that in spring higher amounts of run-off will be observed, while from May to August less run-off, although highly needed, will be available. The Amu Darya River Basin and small water currents are extremely vulnerable to climate change. It is expected that the water flow will potentially decrease by 2-5% in the Syr Darya River Basin and by 10-15% in the Amu Darya River Basin by 2050. During the years of acute water scarcity (assessment for extremely warm and dry years), vegetation flow in the Syr Darya and Amu Darya Rivers Basins might decrease by 25-50% (IPCC-scenario A2). On the other hand, the Second National Communication (SNC 2009) expects that irrigation norms will increase in average by 5% by 2030, 7-10% by 2050, and 12-16% by 2080 in Uzbekistan due to evaporation and warming up.

Temperatures during winter wheat harvest in mid June increasingly exceed 40°C leading to severe yield losses and unfavorable milling properties. Increased evaporation during the growing season will further reduce the production of spring wheat by 27% or more. An increase in the total number of days with temperatures above 40°C is likely to prove unfavorable also for melon and watermelon and decrease cotton yields by 10-40%. An increased frequency of heavy rainstorms will increase run-off and soil erosion. This is particularly important in areas with an annual rainfall of between 500 and 750 mm and insufficient ground cover. The productivity of the rangelands is as well affected by climate change, but adversely in the non-mountainous arid areas with desert vegetation, in the semi-arid regions currently used for summer grazing, and in the sub-humid areas. It is expected that the composition of plant communities in the rangelands used for pasture are significantly altered with consequences to forage production, cattle breeding and production of Karakul sheep. The seasonal timing of rainfall is reported to influence animal live weight and survival to the end of the year, thus requiring different management strategies. SNC expects negative impacts on the reproductive capacities of Karakul sheep due to a 5-11 % increase of thermal loads by September 2030.

Early action to adapt the Uzbek agriculture to these negative effects of climate change and targeted strategies towards further processing agricultural crops is highly desirable concerning GDP, food security, employment and environmental issues. Uzbekistan has recognized that: According to the "Second National Communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change" (SNC 2009) the costs of non-action would be considerably high: By 2050, cotton crop losses caused by lack of irrigation water could achieve 11-13% in the Syr Darya River Basin and 13-23% in the Amu Darya River Basin only due to increased evaporation and reduced flow caused by Climate Change. SNC also points out that a number of adverse factors could lead to agricultural products deficit of 10-15% by 2050 in comparison with the current period.

WBGU (2007) underlines the high conflict potential, in case ethnic groups would make use of environmental and economic changes for their own purposes, for instance in the region of Aral Sea and Fergana valley. Both areas face various threats in consequence of climate change and both are home to different ethnic groups. These groups might be driven into competition in times of water scarcity, further desertification and decreasing income in the agricultural sector. The Fergana valley is the most important area of agricultural cultivation and the most densely populated part of Central Asia. Parts belong to Uzbekistan, Kyrgyzstan and Tajikistan, and even within the Uzbek area of the valley, various ethnic groups live (Uzbek, Kyrgyz, Tajik, Tartar and others). During the last two decades, several conflicts over access to resources erupted along ethnic lines. According to the WBGU, climate change will probably cause increasing loss of valuable arable land, risk of landslides and growing scarcity of usable water resources in summer in the Fergana valley. Non-action might cause social impoverishment – a fuel for ethnic tensions in a border area. In order to decrease the potential of frictions and conflicts, Uzbekistan needs to rapidly anticipate the effects of climate change and the growing demand by population growth in agriculture. Uzbekistan might also consider promoting a common energy strategy within Central Asia in cooperation with multilateral organizations. Exploring the high potential for wind-energy in the neighbor countries (Kazakhstan, Turkmenistan and others) and developing a common energy market might reduce the need to expand hydropower in Kyrgyzstan and Tajikistan and reserve more water for agriculture to ensure food security in Uzbekistan and the CAC.

Uzbekistan has two important assets to cope with the challenge set by climate change: (1) The country has always been a hotspot of biodiversity concerning crop plants and successfully kept a high number of varieties over decades (total 124 agricultural crop species and 952 varieties/hybrids; e.g. 39 species and 389 varieties of vegetable crops and melons; 22 species and 204 varieties of fruit and berry crops; 5 species and 52 varieties of industrial crops; 14 species and 129 varieties of grain crops). (2) Agricultural research has a long tradition and a high standard in Uzbekistan. Specifically in this decade, a lot of promising research findings has been published to adapt to climate change (see below: *Tackle weaknesses: water and soil quality*; *Underutilized plants)*. There are numerous remarkable research institutions in Uzbekistan, e.g. Uzbek Cotton Research Institute, Uzbek Research Institute of Vegetable, Melon Crops and Potato, Uzbek Research Institute of Horticulture, Uzbek Soil Science Institute, Central Asian Research Institute of Irrigation and Drainage (SANIIRI), Uzbek Research Institute of Karakul Sheep Breeding and Ecology of Deserts, Tashkent Institute for Irrigation and Melioration, Andijan University, and the ZEF/UNESCO Khorezm project at Urgench State University (ZEF 2003). The Uzbek government initiated activities towards crop diversification: The area of cotton plantations has been significantly reduced towards an increase of wheat in order to reach higher food security. In 2009 farmers were encouraged to use larger parts of their farms for cultivating vegetables. Especially in the pre-urban zones their share has been increased. However, vegetable and fruit production are still not sufficient to supply the Uzbek population and there is also room to further extend the area of these cash crops and to improve the marketing structures for export.

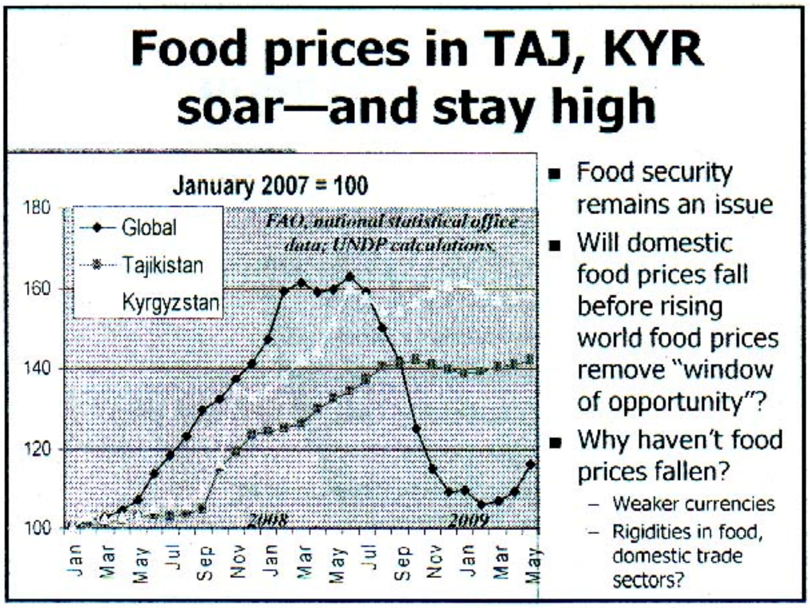
With view to high population growth, land degradation and climate change higher value crops and value chains seem to be favorable to achieve food security within the next decades.

Tajikistan – economy, climate change and agriculture

Tajikistan is one of the poorest countries worldwide, and – as Kyrgyzstan – it is a net food importer. Less than half of Tajikistan's food needs are produced internally (Van Atta 2008). The mountainous country often suffers from food insecurity and humanitarian crises also due to natural hazards, which will increase due to climate change and high population growth (6.8 million in 2008, 10,8 million in 2050 according, as forecasted by the UN (http://esa.un.org/unpp/). 74 % of the population live under the poverty line, in rural areas 76 % (World Bank, cited by UNDP, CARRA 2009a*).* GDP per capita is low, $2.100 a year (2008). Tajikistan is the world's leading country in the proportion of remittances to its GDP: "*Experts estimate that between 600,000 to over one million Tajik migrants work in Russia. In 2007 they sent home over US$1.8 billion through banks, or up to 30 percent of the national GDP. Other sources state that remittances comprise up to 46 percent of Tajikistan's GDP*" (Marat, 2009).

Water, energy and food insecurities, which started in winter 2007-2008, took root in Tajikistan and even spread to Kyrgyzstan, according to UNDP (UNDP, CARRA, 2009b). The prices for bread, a major item in the diet of the Tajik population, especially of its poorest strata, more than doubled between 2007 and 2008. 15 % of the urban population is severely food insecure and 22 % moderately; among the rural population 11 % are severely food insecure and 23 % moderately according to WFP (WFP, 2008).

Figure 4: Food prices in Tajikistan and Kyrgyzstan 2008/09



Source: UNDP (presentation of CARRA) 23.9.09 Tashkent

But on the other hand, the example of the Mountain Societies Development Support Programme (MSDSP) project in the mountainous Gorno-Badakhshan Autonomous Oblast (GBAO) seems to show significant success: It increased food self-sufficiency from 10 % (1993) to 77 % (1999) and 69 % in 2004 (Nygaard et al. , 2005). This project directly provided poor people with access to capital like land and animals, thus giving them the chance to improve their living standard by themselves. Whereas the project focused in the beginning on wheat production, in the second half of the 1990ies farmers were encouraged to grow more potato, vegetables and to (re-)establish orchards.

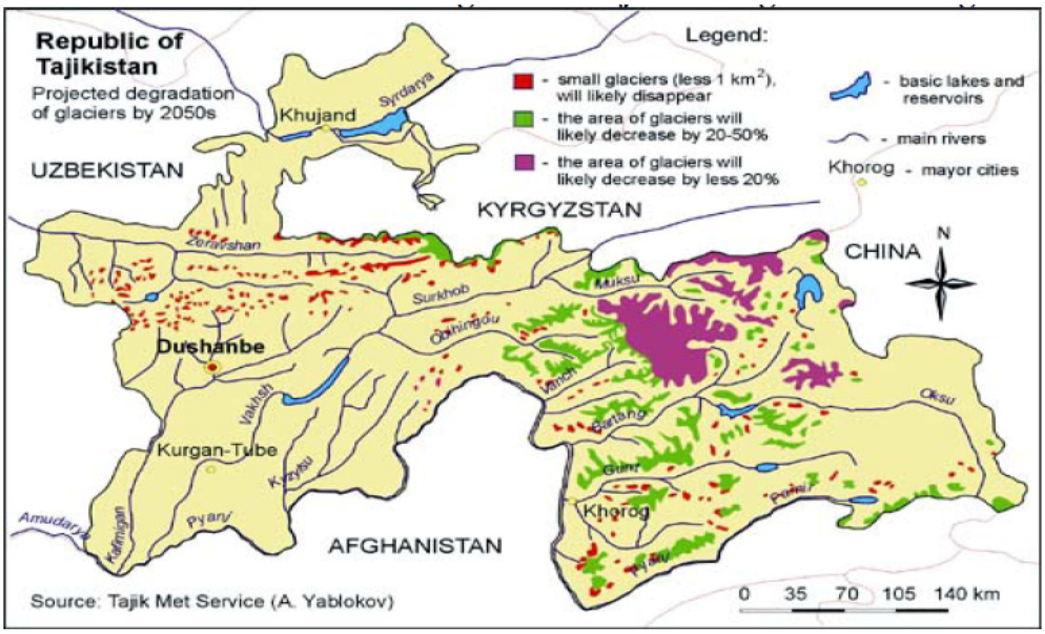
This highly mountainous country offers limited areas to produce food, mainly pastures. At present (population: 6,8 million) there are only 0.14 hectares arable land per capita on average – almost only half the global average of 0.26 hectares per person. In 2050 with a forecast of 10.8 million inhabitants (http://esa.un.org/unpp), further degraded land, desertification and loss of smaller glaciers due to climate change the decline of arable land per capita will be dramatic. The ethnic mix of population (80 % Tajik, 15 % Uzbek, 5 % minorities) might fuel conflicts. Any policy on food security in Tajikistan should also include activities towards achieving a more sustainable birth rate.

Agricultural land has been expanded to marginal sites, land is overused and degrading. Not more than about 7 % of the land can be used by intensive agriculture. Cotton is the major product and causes soil saline and the drying up of the river Panj (Amu Darya). Together with aluminium, cotton is the major source of foreign income. Besides cotton grain, vegetables, fruits and tobacco are grown. Cows, sheep and goats as well as sericulture play an important role.

In consequence of the expected high rise of temperature, IPCC estimates a decrease in crop yield between 2.5-10 % by 2020 and 5-30 % by 2050 in the region. With view to expected higher rainfall and runoff in winter and spring, IPCC recommended in 1996 the expansion of winter crops and more drought-resilient crops (Guelph, 2008). IPCC also expects grasslands to become less productive. Also, changes in the seasonal patterns will affect agriculture in mountainous areas more, because the agricultural season is shorter than in the lowlands of the same region. Robinson et al. (2008) expect benefits for higher altitudes due to longer growing seasons, but as evaporation will increase along increasing temperatures and as smaller glaciers will likely disappear already until 2050, there might not be enough water for farmers and pastoralists to benefit from longer grower seasons. These threats should be regarded as some of the major challenges for research in order to avoid significant setbacks and migration of former pastoralists.

On the long term glacier melt will decrease river flows within the Vakhsh, Kafarnigan, Kyzylsu, Zeravshan and other river basins significantly. Except risks of floods during the next decades, agriculture (and hydroenergy) will be affected seriously as they will lose their main water resource also by the disappearance of various small glaciers, which are regionally of high importance. At present irrigation systems in Tajikistan are quite inefficient; knowledge on irrigations systems is low. To avoid erosion, floods and mudslides in the mountainous regions reforestation, limiting ploughing on steep slopes and other measures like afforestation are needed. Perelet expects an increase of Malaria due to climate change (Perelet, 2007) in Tajikistan, which should be taken into consideration in the field of irrigation technology.

Figure 5: Projected degradation of glaciers by 2050s

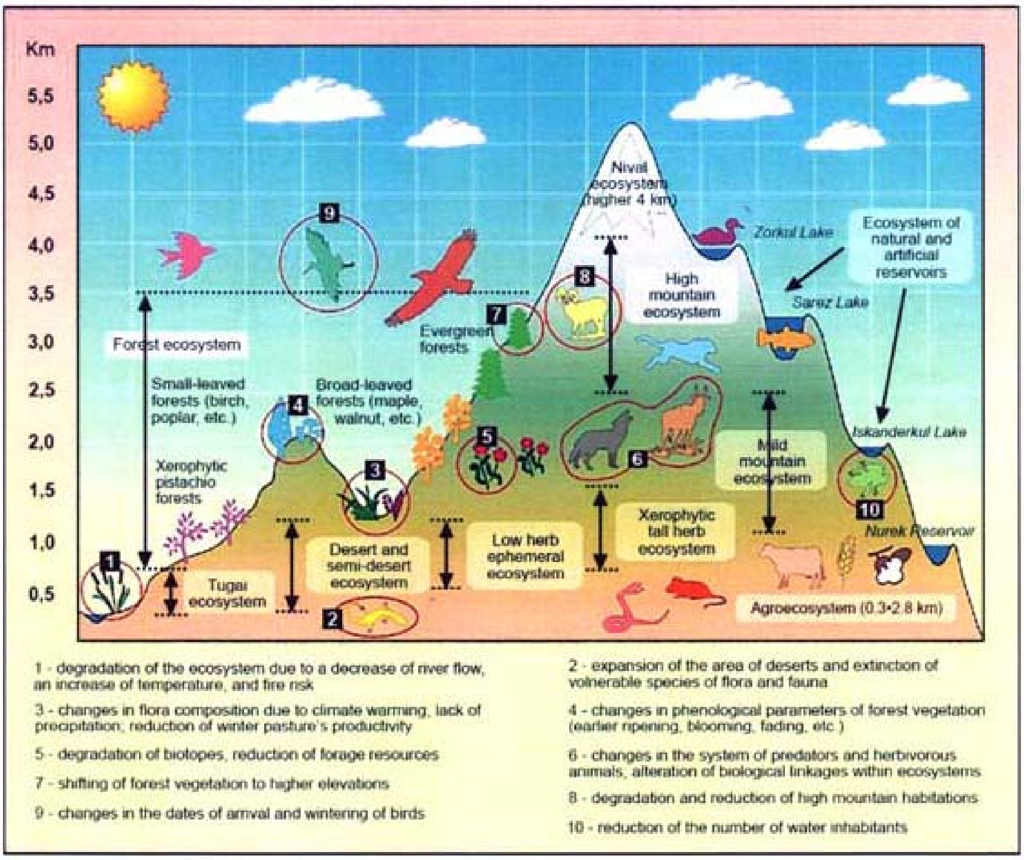


Source: Tajikistan 2002: State of the Environment Report, cited by Perelet 2007

It might be misleading to describe just the changes in ecosystems caused by climate change without integration of human beings as done by University of Guelph/World Food Programme in their paper on food security and climate change in Tajikistan (Guelph, 2008). Mankind is one of the main driving forces of changes. Agriculture, settlements, transport ways and industry highly influence the changes in ecosystems, caused by climate change.

Is it for instance likely that evergreen forests really shift to higher elevations (which might take more time than climate change offers in high mountain regions anyway) – or is it likely that people sell off the forests for industrial purposes, that they chop firewood and use the land even for a short period for their herds, thus fueling erosion and desertification? Due to increasing poverty caused by ongoing climate change the run on all natural resources might increase and destroy, what is left by nature or whatever adaption ways the ecosystems develop themselves. Therefore, agricultural research is challenged to develop methods, crops, animals and value chains, which allow villages and farmers to make their income in the place they are now. If they have to migrate, to build new settlements etc. the stress on the environment will be multiplied. Ecosystem services would be put at risk to an even higher extent.

Figure 6: Distribution of Tajikistan's ecosystems according to vertical zonation and expected impacts of climate change



Source: I. Abdulsalyamov; V. Novikov, Guelph 2008

Tajikistan will need assistance to develop an integrated adaptation strategy on climate change, which avoids high chronic food insecurities during the next decades. For remote mountain areas as much self-sufficiency as possible and sustainable production of high quality goods like herbs for medical use might be favorable. But with respect to high population growth and high vulnerability to climate change value chains (vegetables, fruits, tobacco) instead of cotton and grain might be a strategy to reach more food security. Due to the high number of men migrating from Tajikistan, gender-related research is needed.

Georgia – economy, climate change and agriculture

Georgia is not among the poorest countries within the CAC region, but GDP per capita of $4,700 per year is low. The agricultural sector is contributing about 12.8% to GDP (2008) in Georgia. Its share had declined since 2004, when other sectors of the economy, such as services and transportation started to grow. This growth resulted from dramatic improvement of business environment in Georgia through reduction of number of taxes and licenses a business is required to operate, simplification of procedures for opening new businesses and regimes for importation and a significant success, which was made in combating corruption in the country and establishing transparency in the government activities.

But with view to employment, Georgia is still largely an agricultural country. As much as 47 % of the population lives in rural areas and about 44 % economically active population is self-employed in the agricultural sector. The diverse climate and rich soils of Georgia support a great variability of crop production. Georgia is famous for its wine, temperate fruits and vegetables that are mostly produced in East Georgia, while large areas of tea, citruses, subtropical fruits and nuts are found in West Georgia. Maize, wheat, barley and sunflower prevail among the field crops.

Under overall policy directed towards improvement of business environment, some important government agricultural services such as variety release and seed quality control were discontinued, while the phyto-quarantine control significantly weakened. Direct application of economic theories from the industrial and service sectors to agriculture put on the edge of economic viability not only small farmers, but also large producers that can hardly compete with producers from neighboring countries (Turkey, Azerbaijan, Armenia, etc.), where agricultural production is mostly subsidized.

Agricultural production in Georgia has still to reach the levels of the last decade of the Soviet Era. The crop productivity is in average 20-30% lower than it was in 1980-ies. The following factors of the low crop productivity are recognized in Georgia: land fragmentation, ceasing of investments by farmers in new machinery, inputs and technologies due to overall poor financial status of the farmers, decline in resource base due to irrational farming, collapsed state infrastructure of agricultural production support (seed production, research, extension, etc.) and inefficiencies in marketing of agricultural products and key inputs to farmers.

Studies of temperature dynamics in Georgia have revealed noticeable warming of up to 0.5^0C in the east and slight cooling up to 0.3^0C in the west (CEO 2002) for several preceding decades. Later studies showed that the highest impact of climate change is exerted through increased number of windy days and heavy rainstorms in Georgia, which promoted run-off and soil erosion. As of 1981, as much as 205,700 ha out of 673,200 of arable land were eroded in Georgia due to irrational farming practices. About 600 thousand ha of pastures (out of 1.8 million ha) were eroded due to overgrazing. Studies based on the several climate change scenarios forecasted that an increase in the mean annual temperature by $3\text{-}5^0C$ will be accompanied by a decrease of precipitation by about 9-13% both in Western and Eastern Georgia up to the year of 2100. This process will be especially sharpening in summer, when both the temperature increase and precipitation decrease tendencies are more exposed than in other seasons.

The most vulnerable part of the country in terms of climate change is East Georgia, which is semi-arid and where drought is observed in every 5-7 years. The droughty years are characterized by yield reductions for up to 50-70% in average in all rainfed crops of the East. Based on the Dedoplistskaro district studies, Georgia's "Second National Communication to the UNFCCC" (SCN) suggests that the anticipated changes in climatic parameters will accelerate the wind erosion of land and extend the duration of drought. According to this forecast, the air temperature will increase and air humidity index will decrease. This process will be accompanied by unchanged and even declining rainfall resulting in the increase of soil erosion. The fertility of agricultural lands and pastures will be further decreased by the growing erosion and increased deficit of water. Water deficit for wheat will probably grow further by 73% which will affect its quality and especially its nutritional value. A further 17% deficit of water is predicted for sunflower crops, and a 29% deficit for pastures. There will be high impact on yield and quality of vineyards of East Georgia, which are the mainstay of the Georgian agricultural sector. These will have social implications as farmers will have to abandon land, which will rise in unemployment and poverty. Due to forecasts there will be a slight decrease of population, so that migration to urban areas caused by decreasing income in agriculture might cause less problems in Georgia than in Central Asia.

In West Georgia, the main risk-factors are land erosion and landslides. According to SCN, at the first stage this process will be provoked by the growth in precipitation, and afterwards – by the increase in the duration of drought, the tendency to which is being already observed. The growth in the pest population both in crops and in forests is also anticipated. The high risk of landslide activity results in the abandonment of settlements by the population and causes for its turn the rise in unemployment and in poverty.

Georgia is a mountainous country, which may aggregate negative impact of climate change. About 54% of the area is found higher than 1000 m above the sea level. Data of National Service for Environment of Georgia suggests only about 360 thousand ha of arable land (out of 673,200 ha) is flat lowlands without slope (0-2^0), while as much as 156,000 ha (25% of the total arable land) have slope more than 5^0. On average there are only 0,179 ha arable land per capita. In the mountains, crops are often grown on hills, slopes and depressions, where shallow and underdeveloped soils prevail. Large areas of pastures cover slopes and hills. Mountain soils of Georgia are very susceptible to water and wind-caused erosion and degrade fast due to irrational farming or overgrazing. There is a need for practices that reduce erosion of soil such as bench terraces, reduced or no-tillage, planting perennial grasses in strips across the slope, contour plowing, afforestation, planting tree crops on the slope etc.

Georgia used to be an exclusive supplier of tea and citruses and one of the biggest exporters of wine and fruits within the closed market of the Soviet Union. After obtaining independence, Russia remained Georgia's major market for most of the agricultural products. However, the political tensions, which started in 2004, resulted in banning of Georgian exports by Russia, which had a very harming impact on the Georgian agricultural sector. Hostilities that aggravated in August of 2008 delayed normalization of trade relationship between Russia and Georgia for uncertain time. The country needs to access international agricultural markets, such as EU, which are very competitive and demanding in terms of food quality and safety. There is a need for improved post-harvest handling technologies and enhanced food safety through introduction of better quality and food hygiene management systems, as well as certification procedures.

Georgia has important assets to promote agricultural production. First of all, it is rich of biodiversity: there are more than 2000 species of plants in Georgia that have direct importance for food, timber, edible fruits and nuts, forage and fodder, medicine, colorants, industry and essential oil production. The latest official edition of the Catalogue of the Georgian Released Varieties of 1997 listed 195 varieties of field and vegetable crops and 196 varieties of fruit trees. There are numerous scientific and educational centers that could contribute to sustainable intensification and diversification of agricultural production in Georgia and improvement of linkages between the Georgian producers and international markets.

By intensified export chains for instance to Europe (labeled wine, labeled fruits and vegetables) might get good income to purchase grain for own consumption.

4. Current Agricultural Production in CAC

Wheat

Wheat is the main staple food in all countries in the CAC, and is expected to remain that way since there is little indication of any dietary shift to other cereals in foreseeable future in this region. Since it accounts for more than 80% of area cultivated and crop harvested for all cereals in the CAC (calculations based on data from FAO, 2009), wheat plays a pivotal role in food security in the region. Wheat occupies approximately 16 million hectares and production stands at 28 million tons. This shows that average wheat productivity in the region is about 1.75 t/ha which is the lowest compared to wheat yields in its adjoining regions West Asia (2.12 t/ha) and Eastern Europe (2.35 t/ha) and in Asia (2.89 t/ha) and the world (2.83 t/ha) on the whole. In the past five years, area, production and productivity of wheat have shown annual growth rate of 1.5%, 2.9% and 4.2%, respectively. A remarkable improvement in productivity has been achieved under irrigated wheat management, in particular on about one million hectares in Uzbekistan, where yields of 4.6 t/ha were achieved in 2009. However, these gains in wheat productivity, and thus food security are threatened by serious production constraints such as drought, heat, soil salinity and persistent diseases. Shift in climatic elements, global warming in particular, is expected to exacerbate the adverse effects of the prevalent biotic and abiotic stresses on wheat productivity in the CAC region.

Table 2: Production of wheat in CAC

CAC Countries	Wheat					
	1992			2009		
	Production, t	Area, ha	Yield, t/ha	Production, t	Area, ha	Yield, t/ha
Armenia	141.483	65.500	2,2	252.000	105.000	2,4
Azerbaijan	943.300	435.000	2,2	2.160.000	800.000	2,7
Georgia	191.000	107.900	1,8	137.700	81.000	1,7
Kazakhstan	18.285.008	13.722.900	1,3	17.987.000	13.836.000	1,3
Kyrgyzstan	679.000	248.400	2,7	1.200.000	500.000	2,4
Tajikistan	170.405	183.500	0,9	918.000	459.000	2,0
Turkmenistan	377.000	197.000	1,9	1. 736.600	914.000	1,9
Uzbekistan	964.000	626.990	1,5	6.062.000	1.310.000	4,6

Source: FAOSTAT 2009 and NARS Sources

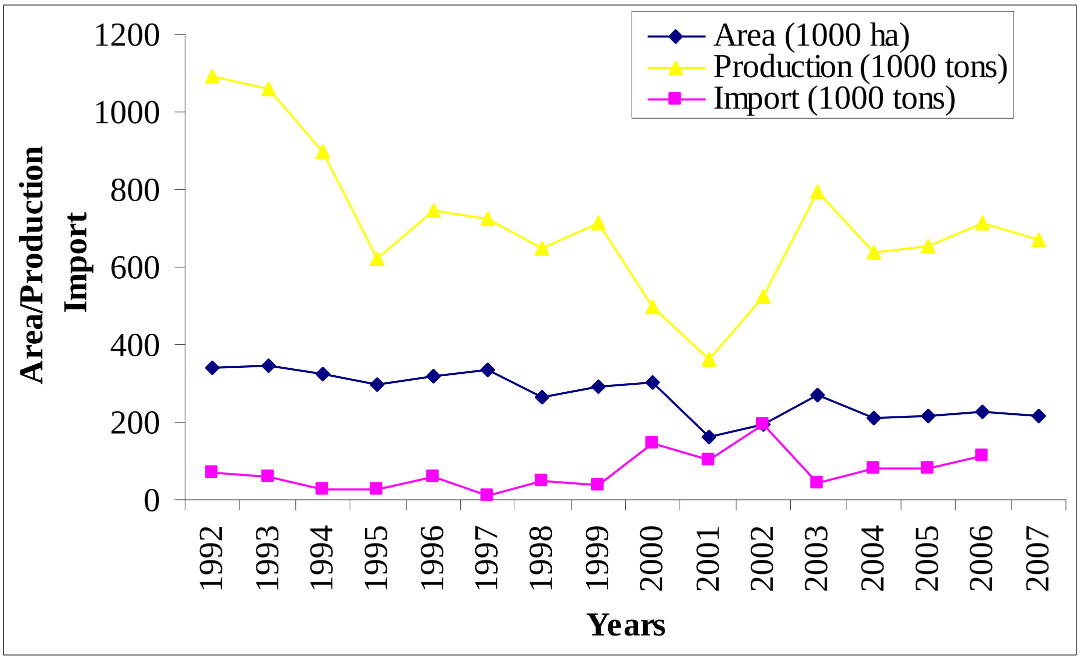
There is a need to develop highly water-productive wheat for irrigated management and drought tolerant varieties for rainfed management. Terminal heat stress is a serious problem, in particular, to spring-planted wheat. Higher temperatures resulting from any future climate change could affect wheat physiology in several ways, depending on crop growth stages. Higher temperatures during flowering can reduce the number of grain set in wheat spikes. High temperatures during post-flowering stage could reduce size of the grains. Both preceding conditions would cause substantial reductions in grain yield. Heat-tolerant wheat varieties would not only improve productivity of commonly spring planted wheat, but could also bring additional areas under cultivation which are currently not planted during fall due to lack of soil moisture. In large part of Central Asian countries, wheat cultivation is done under irrigated management causing the risk of salinity. Development of salinity tolerant wheat varieties as well as management of saline soils to make them suitable for wheat cultivation will provide a huge boost to wheat productivity and hence food security in Central Asia because crop yield losses due to salinity are estimated at 30% in Uzbekistan, 40% in Turkmenistan, 30-33% in Kazakhstan, 18% in Tajikistan, and 20% in Kyrgyzstan.

Rice

Rice systems are sources of methane and increase climate change, which also heavily affects them due to high water consumption and low heat tolerance of rice. Therefore, this main staple food for more than half the world population is “*under increasing pressure*” (FAO, 2008). The ecological footprint is quite large due to high water consumption (see Figure 17) and greenhouse gases.

At present, rice is the second most important cereal crop after wheat. It is an important part of the national diet particularly in Uzbekistan and Tajikistan, where it forms the basis for the national dish, *plov.* Per capita consumption of rice is about 20 to 25 kg per year (Ismali, 2006). In Central Asia , income from cotton and wheat is very low and gross margin is mostly negative (Djanibekov, 2008, Ismail 2005) while rice is a remunerative crop which fetches a price several times higher than that of wheat and 2-3 times higher than the world price. In the Caucasus, rice is grown only in Azerbaijan on 1000 ha. In the CAC region, mainly temperate japonica rice is grown under irrigated condition near river basins. The total rice area in the region was about 341,000 ha in 1992, but it decreased in the last sixteen years and became 214,486 ha in 2007 (FAOSTAT, 2009). In 2007, on an average, 41% of total rice area in Central Asia was in Kazakhstan, followed by 26% in Uzbekistan, 23% in Turkmenistan, 8% in Tajikistan and 3% in Kyrgyzstan (FAOSTAT, 2009). The current area under rice production in the region is relatively small. Rice productivity might be significantly improved through introduction of suitable varieties and efficient technologies that has already been established in other regions. At present rice is mainly imported.

Figure 7: Total area, production and import of rice in Central Asian republics from 1992 to 2007



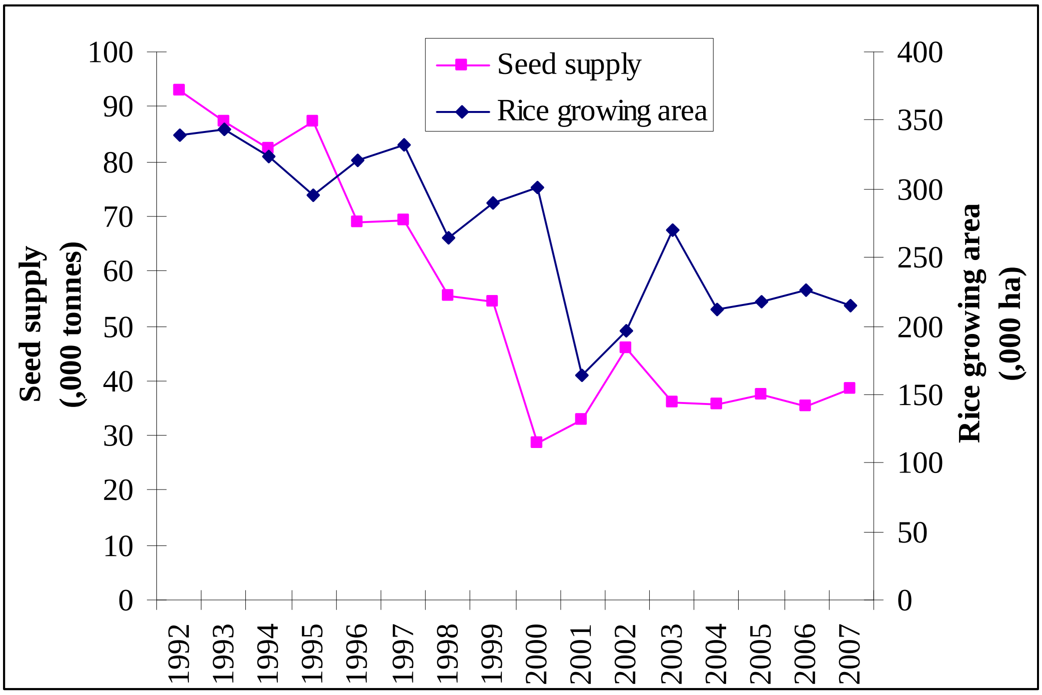
Source: FAOSTAT, 2009

Rice research in the region has been dwindling since independence due to lack of national and international support. Infrastructure for rice research and production is seriously lacking (Ismail, 2006). However, Uzbekistan and Kazakhstan hold special rice research institutes, Tajikistan, Azerbaijan, Kyrgyzstan have special research units and Turkmenistan plans to establish a Rice Department under the Grain Research Institute. Presently, private companies are gradually starting to be involved in rice research in some of the countries. Current rice breeding targets are higher yield, early maturity, lodging resistance, resistance to salinity, higher water use efficiency and breeding new rice varieties for the introduction of a new rice-wheat crop rotation..

Drought, salinity and low temperature are the major constraints for growing rice in Central Asia, therefore it would be more favorable to grow aerobic rice[12]. But all varieties released so far are adopted to irrigated conditions and have low water use efficiency. Availability of good quality seed has been declining since the start of rice cultivation. National seed production and seed distribution systems are supplying only a fraction of the need. Most of the seed in the region is supplied through farmers-to-farmers exchange and based on farmers' own storage. As a result, seed is often of poor quality and mixed.

[12] Growing rice in non-flooded, non-puddled condition i.e. growing rice like maize and wheat

Figure 8: Situation of seed supply and rice area in Central Asian republics

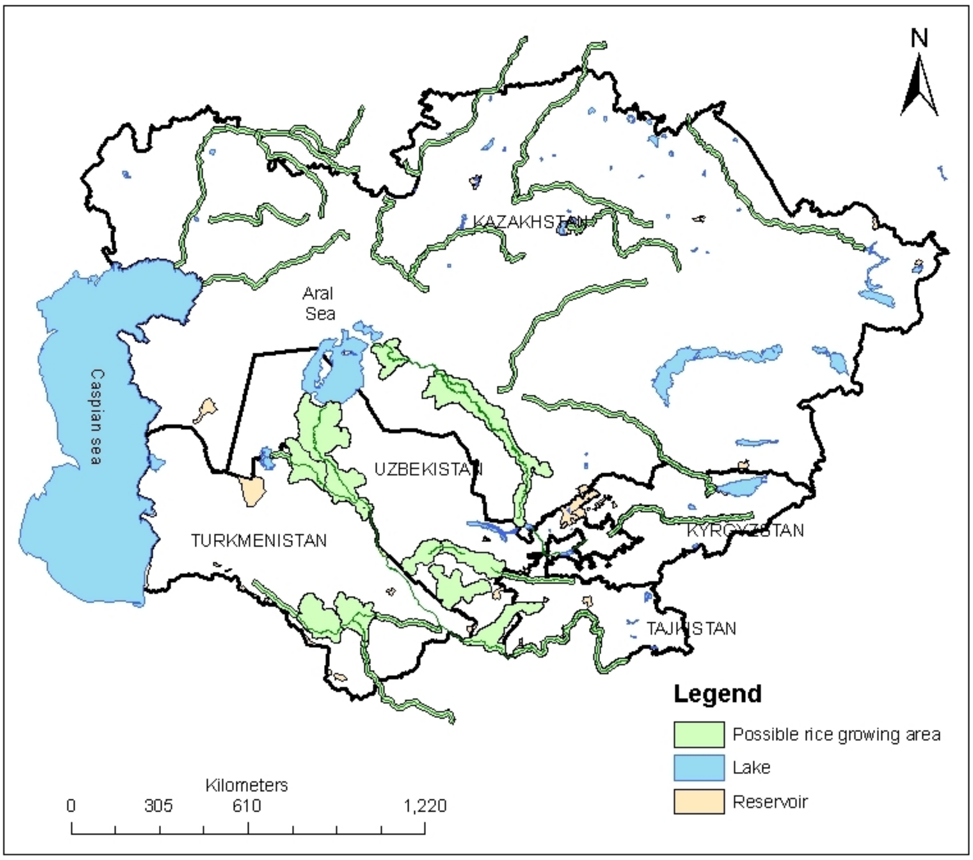


Source, FAOSTAT, 2009

Water losses in rice fields are very high due to poor canal maintenance, inefficient water distribution systems and poor water management practices. Rice fields have not been leveled for more than 14 years in this region (Ismali, 2006). The current direct-seeding crop establishment method involves excessive use of seed (~220 kg per hectare) with excessive use of water (fields are submerged with more than 20 cm of water during most of the growing period). Over-irrigation is the major mechanism for controlling weed species like *Echinochloa* sp and *Cyperus* sp. Existing rice varieties have poor tillering capacity, but to compete with weeds they would require high tillering and fast growing rice varieties. Proper leveling and use of pre-germinated seeds in direct seeding condition can substantially reduce water application.

Transplanting might be the best option to grow two crops a year either in rice-wheat or wheat-rice rotations, as there must be at least one month relaying of two crops due to cold winters. Planting rice inside wheat or maize is very difficult and not in practice. But seedlings can be grown in nurseries for 20-25 days. This can save more than 5000 m^3 ha^{-1} irrigation water as farmers would not need to keep the more than 20 cm water level they are currently applying during the initial crop stages. Transplanting with short duration varieties (85-100 days varieties) can increase the possibility of growing two crops a year, according to research in the ZEF/UNESCO-Khorezm-project. As water is still cold during the time of rice transplanting i.e. in May-June, it is very difficult to do manual transplanting. The costs of transplanting are also very high. Rice-growing farmers might benefit from mechanical transplanters (if built from local material, they cost only around 100-150 US$). Based on nurseries and mechanical transplanting, improved rice varieties might be grown also in areas with less water availability and in waterlogged soils with high salinity, but both possibilities require also better field management.

Figure 9: Possible rice growing area in Central Asian republics



Source: Devkota et al., 2009 unpublished

Aerobic rice combined with a proper residue application can reduce water application substantially. In the experiment conducteat the ZEF/UNESCO Khorezm Project in 2008 (Uzbekistan), aerobic rice saved irrigation water up to 76 %, but had a yield penalty of up to 33% (Devkota et al., 2008 unpublished).

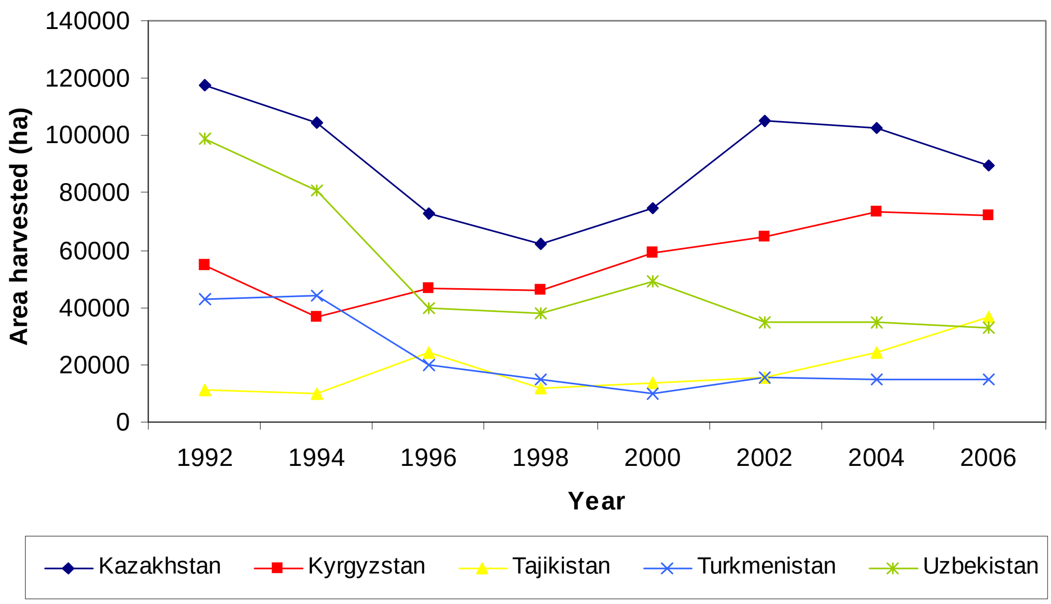
On the other hand, perspectives of rice in Central Asia might be limited due to the rapid warming during spring time. Rice needs 20-38°C. If farmers plant rice before May 15, its germination is very slow due to cold temperature effect. If they plant in July 1 or after that, germination percentage decreases due to very high temperature. At present there is a small window of opportunity: rice planted between May 25 to June 10 can escape both from low and high temperatures. But the predicted regional increase of temperature by 3-4°C is a high challenge for research and breeding.

Maize

Maize constitutes 60 % of the world coarse-grain production (Falcon, 1998), but in CAC, maize still is among the less used crops with the only exception of Georgia. Most of the production is used for fodder, but in Kazakhstan, Uzbekistan and Georgia maize is as well used for human consumption.

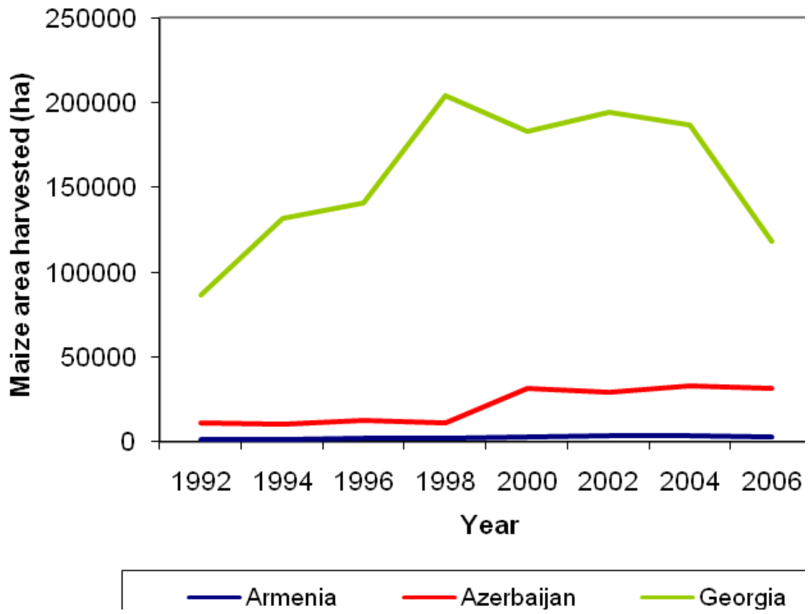
It is grown on all levels of farms (agricultural cooperatives, private farms, household plots), but mainly on household plots (Djanibekov 2008, World Food Program 2008). Maize grows in rainfed and irrigated regions. Irrigation needs around 500-600 mm/ha, evapotranspiration is around 700 mm/ha (Conrad 2006). Fertilizer recommendations in irrigated conditions (Uzbekistan) are similar for fodder maize and maize: 220 kg/ha N, 140 kg/ha P, and 90 kg/ha K.

Figure 10: Harvested area of maize in the 5 Central Asian countries since 1991



Source: FAOSTAT 2009

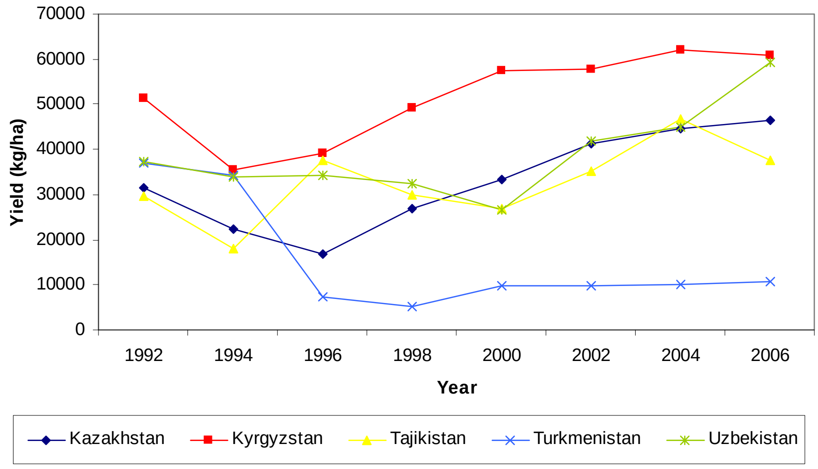
Figure 11: Harvested area of maize in Armenia, Azerbaijan and Georgia since 1992



Source: FAOSTAT 2009

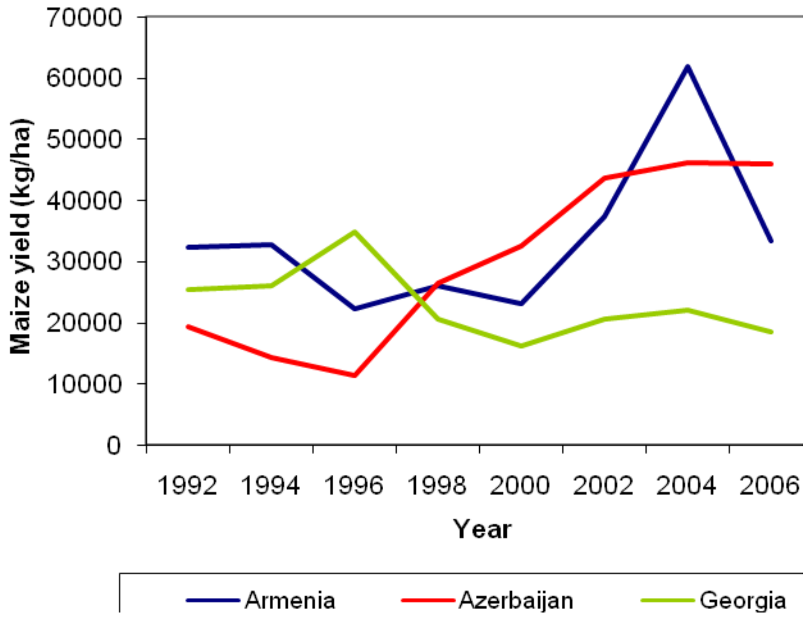
Maize is also grown as single crop (slow-maturing), sown early in spring and harvested after full ripeness of grains. It is used primarily for poultry and livestock feeding (maize grains, and the byproduct, the maize stem). More often it is grown as summer-crop (fast maturing) for fodder maize; i.e. after winter wheat harvest, and is often cut as green biomass before its full ripeness.

Figure 12: Average (green biomass) maize yield (kg/ha) in the Central Asian countries after 1991



Source: FAOSTAT 2009

Figure 13: Maize yield in Armenia, Azerbaijan and Georgia after 1992



Source: FAOSTAT 2009

A reduction of maize production and other fodder caused also decline in poultry, egg production, and metabolizable energy (Djanibekov 2008). In simulations (Djanibekov 2007) assuming an increase in livestock productivity, producers would prefer increasing the production of short season fodder crops such as maize, which are used for feeding their livestock. Other simulations (Bobojonov 2008) also showed that under water-scarce conditions the area of maize may increase due to medium water consumption, fodder and income security.

Maize can handle well with increased CO_2 air-levels and higher temperature. Therefore maize can be regarded as a suitable crop in ongoing climate change, but it is not as salt- and drought-resistant as sorghum.

Potato

Potato is the second main staple after wheat in most of CAC countries, except for Uzbekistan. In Kyrgyzstan, potato is an important source of income since according to official data potato exports are worth around US$ 232.4 million/year (CIP, 2009). Before the collapse, Soviet Union was the world's largest potato producer and the potato industry (like any other sphere of the economy) of each republic within USSR was functioning under the centrally-planned economy. During those times, the potato industry did not experience any significant changes since there were guaranteed marketing and supply channels. Kazakhstan was the largest potato producer among CAC countries with an output of more than 2 mln tons, accounting for about two thirds of total area planted and production in the region. Apart from Turkmenistan13 that played a very insignificant role with less than 30 thsd tons produced annually, the output in the remaining countries ranged from 170.000 to 400.000 tons (Ibragimov et al., 2009).

Following the breakup of the Soviet Union in 1991, the former USSR republics faced with need for reorganization and restructuring created by changes in the new political and legal environment. This was also true for the potato industry of CAC countries which experienced dramatic variations in the area planted, production and productivity. The growth in potato production was more evident in Central Asia compared with the Caucasus region, with all the five CA republics achieving more significant increases in potato output. In particular, extrapolating data from official statistics (Ibragimov et al., 2009), Kyrgyzstan reached 10.3% average annual growth rate in potato production since independence, Tajikistan 9.7% and Uzbekistan 8.2%. The highest yearly growth rate, however, was observed in Azerbaijan (13.4%), while in Armenia it was less impressive (6.0%). The increase of production was largely due to an expansion of cultivated area that interested all the countries except for Kazakhstan and Georgia, the latter being the country where the potato industry demonstrated the most unpredictable output trends both before and after the independence (Ibragimov et al., 2009). As of January 2008, potato production in CAC countries stood at 7.7 million tons, covering more than 470.000 hectares (Ibragimov et al., 2009). While Kazakhstan remains the largest potato producer in the region with an output equivalent to 2.4 million tons, Tajikistan is now a clear leader in terms of productivity with slightly more than 22 tons per hectare. With an annual per capita potato consumption of 143 kg recorded for 2005, Kyrgyzstan ranks second only to Belarus in the world (FAO).

Table 3: Production of potato in CAC

	Potato					
	1992			2007		
CAC Countries	Production, t	Area, ha	Yield, t/ha	Production, t	Area, ha	Yield, t/ha
Armenia	322.400	29.000	11,1	579.600	31.600	18,3
Azerbaijan	156.000	19.000	10,4	1.037.300	67.100	15,5
Georgia	210.800	21.900	9,6	229.200	21.200	10,8
Kazakhstan	2.569.700	242.600	10,6	2.414.800	155.000	15,6
Kyrgyzstan	362.000	27.200	13,3	1.373.800	86.400	15,9
Tajikistan	167.400	13.000	12,9	662.100	30.300	21,9
Turkmenistan	35.000	3.000	11,7	150.000	26.800	5,9
Uzbekistan	365.300	42.900	8,5	1.188.100	56.000	21,2

Source: FAOSTAT 2007

[13] Statistical information on Turkmenistan was taken from FAOSTAT website

Despite the fact that the potato industry in CAC region significantly changed following independence, wheat still remains the most important staple crop in these republics. Similar to potato commodity, Kazakhstan is also the largest wheat producer in CAC region with an output of 16.5 million tons, partially exported, while Uzbekistan and Turkmenistan have reached self-sufficiency in grain production since gaining the independence (Ibragimov et al., 2009). In terms of comparison, growth rates in wheat production were higher than potato in Armenia, Uzbekistan, Tajikistan and Turkmenistan while in the other countries it was the opposite if we take 1992 as a base year. On the other hand, while for wheat the growth in production in countries like Armenia, Uzbekistan and Tajikistan was largely due to significant increases of the cultivated area, for potato it was more due to an increased productivity. In comparison with wheat that remains the main staple in the whole CAC, potato production has shown a more marked increase after the independence, easily confirming its position of second staple crop after wheat.

All CAC countries do not have an efficient potato seed production system to provide clean seed sold at an affordable price to potato farmers. The cost of seeds is high due to lobbyism in Europe and transportation.

The potato – unlike major cereals – is not a globally traded commodity. Only a fraction of total production enters foreign trade, and potato prices are determined usually by local production costs, not by the vagaries of international markets (FAOSTAT 2008). It is, therefore, a highly recommended food security crop that can help low-income farmers and vulnerable consumers ride out extreme events in world food supply and demand. The potato should be a major component in strategies aimed at providing nutritious food for the poor and hungry[14]. It is ideally suited to places where land is limited and labor is abundant, conditions that characterize much of the developing world. The potato produces more nutritious food more quickly, on less land, and in harsher climates than any other major crop - up to 85 percent of the plant is edible human food, compared to around 50% in cereals (FAO 2008c).

Barley

Barley is an important crop in CAC and can plays a prominent role in food security in the region. More than 90% of barley produced in CAC is used as animal feed. However, barley is also used as staple food in the highlands of CAC, where other cereals do not grow properly because of low rainfall, altitude, or soil salinity. Barley remains the most grown cereal in dry areas with less than 300 mm of rainfall, and under production systems with limited alternative food crops, such as in the highlands and the mountains. Because of its adaptation to harsh environments and marginal soils, barley will serve as better buffering of cereal production under the climate change scenario.

[14] Potatoes are rich in carbohydrates, making them a good source of energy. They contain good amount of vitamins B1, B3 and B6 and minerals such as potassium (a fifth of the recommended daily value), phosphorus and magnesium, and have folate, pantothenic acid and riboflavin. They contain iron and are also very rich in vitamin C - a single medium-sized potato contains about half the recommended daily intake - which promotes iron absorption. Potatoes also contain dietary antioxidants, which may play a part in preventing diseases related to ageing, and dietary fibre, which benefits health (FAO, 2008c).

Table 4: Production of Barley in CAC

CAC Countries	Barley					
	1992			2007		
	Production, t	Area, ha	Yield, t/ha	Production, t	Area, ha	Yield, t/ha
Armenia	150.900	92.851	1,6	162.533	97.880	1,7
Azerbaijan	354.200	176.000	2,0	474.646	203.716	2,3
Georgia	75.100	44.500	1,7	40.300	26.900	1,5
Kazakhstan	8.511.000	5.627.400	1,5	2.441.190	1.837.800	1,3
Kyrgyzstan	620.500	263.500	2,4	227.236	125.399	1,8
Tajikistan	41.514	55.000	0,8	71.039	42.300	1,7
Turkmenistan	127.000	60.529	2,1	58.700	61.000	1,0
Uzbekistan	286.600	304.000	0,9	90.000	51.000	1,8

Source: FAOSTAT 2009

Barley occupies approximately 2.5 million hectares and production stands at 3.6 million tons. This shows that average barley productivity in the region is about 1.46 t/ha which is the lowest compared to barley yields in its adjoining regions West Asia (1.55 t/ha) and Eastern Europe (3.03 t/ha) and in Asia (1.75 t/ha) and the world (2.41 t/ha) on the whole. There are several constraints to barley production in CAC that need to be addressed in order to improve productivity. The major abiotic stresses are drought, heat, soil salinity and poor nutritional status of soil; the major biotic constraints are diseases (*Helminthosporium* and smuts).

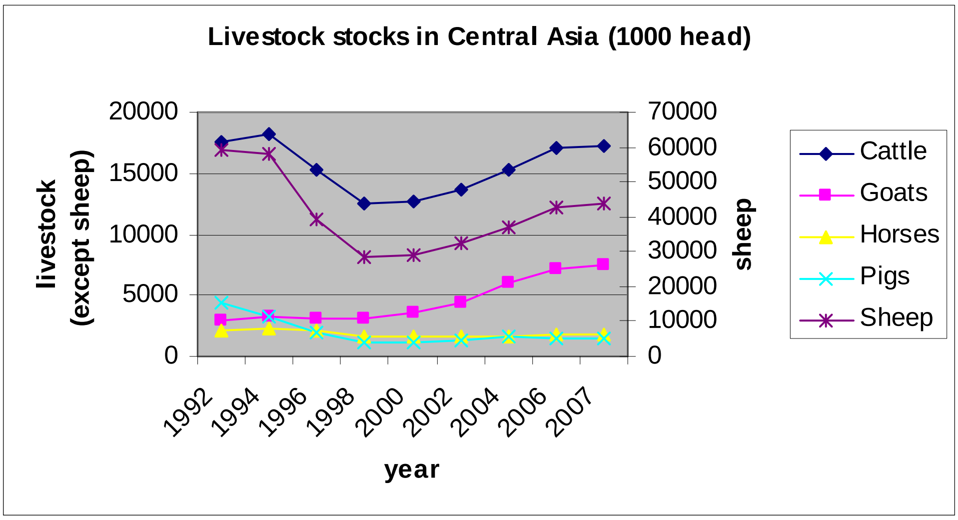
In order to improve food security in CAC, barley will keep playing an important role, primarily through feed supply, and to certain extent the crucial food supply for poverty stricken population in the highlands. High yielding barely varieties with early maturity, resistance to diseases and pests, and tolerance to drought, heat and salinity are needed.

Meat

Livestock production contributes to global warming from methane production, and is also itself affected by climate change, for instance by changing grassland ecosystems and the drying up of smaller natural water resources, which are necessary for cost-effective herding of sheep and goats. Concerning the energy and water balance of meat (see also below: virtual water) meat of sheep and goat has a much smaller ecological footprint than cattle, as sheep and goats are mostly fed on grass and hay, but nevertheless it still has a larger footprint than plant-based food. The risk of fueling desertification by keeping goats on already degraded rangelands is not covered in this paper, but in the context of climate change, research on this topic would be needed.

Livestock production in Central Asia plays an important role for livelihoods of rural households. Following the collapse of the Soviet Union, livestock numbers have dramatically decreased due to several reasons including transformation of the former state collective farms, destruction of the existing input supply systems, decreased income of population. The number of reared livestock started to recover after the economic crisis in 1998. However, the livestock flocks are still below the level recorded in 1992 except for the goat flock that has doubled from 1992 to 2007.

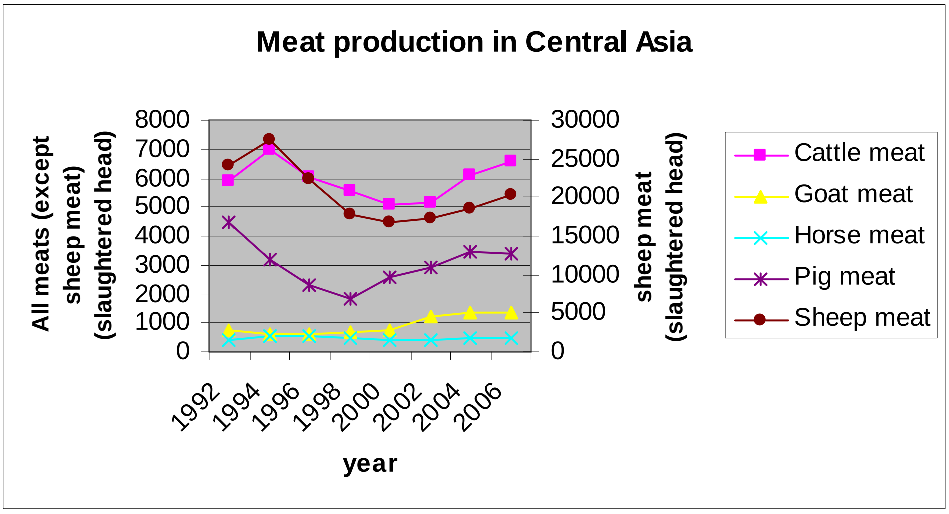
Figure 14: Livestock in Central Asia



Source: FAOSTAT, 2009

Meat production in Central Asia, in general, followed similar trends observed in livestock production. But the production of both sheep and cattle meat began increasing after the decline only after 2000 that is mainly attributed to the low reproduction capacity of animal stocks that have been shrinking till 1998.

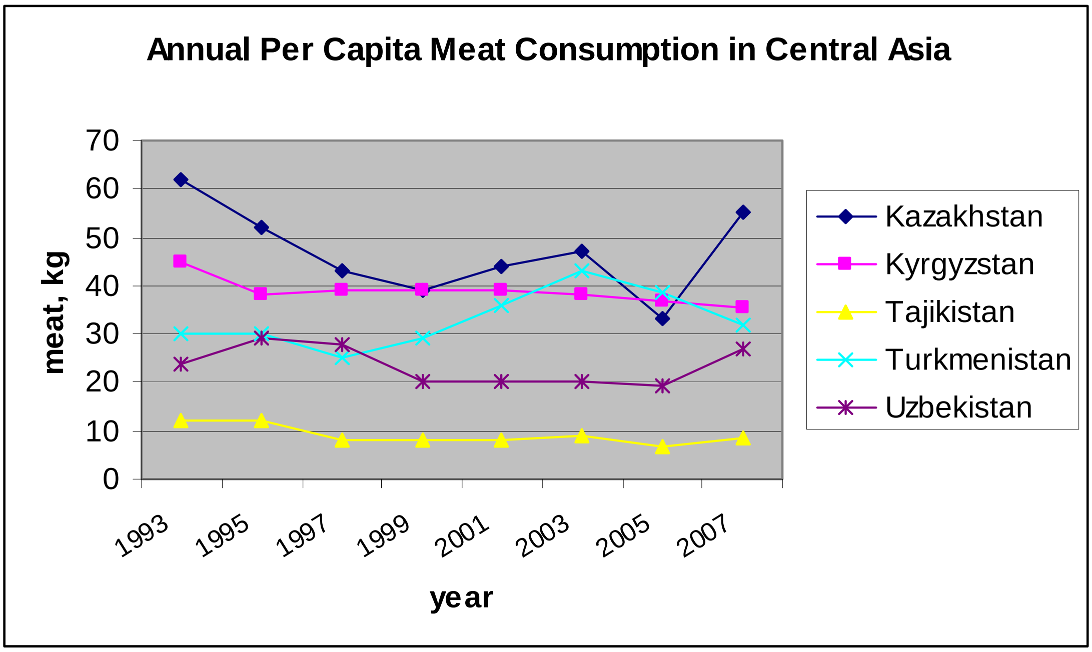
Figure 15: Meat production in Central Asia



Source: FAOSTAT, 2009

FAO data on meat consumption followed different trends in the five Central Asian republics. In Kazakhstan, by 1999 it has fallen down from 62 kg/year to 39 kg/year mainly because of the low income of population. By 2007 it has increased and formed 55 kg/year. In Kyrgyzstan, per capita meat consumption has decreased from 45 kg/year to 35 kg/year from 1993 to 2007. The most critical situation with meat consumption is in Tajikistan where each person has been consuming less than 10 kg of meat per year, which is four times lower than the world average per capita meat consumption. In general, per capita meat consumption is still low in Central Asia except Kazakhstan.

Figure 16: Annual per capita meat consumption in Central Asia



Source: FAOSTAT, 2009

Several factors may negatively affect the future consumption habits of the population in CAC: the economic crisis that started in late 2008 and led to lower incomes and hikes of unemployment (although the effects of this may not last for long; end of 2009 the world economy already shows signs of recovery); high population growth; increasing livestock flocks putting pressure on and exceeding carrying capacity of rangelands that hinder sustainable livestock production; warming up will significantly change the grassland ecosystems and thus alter food and forage conditions; high feed / forage prices restricting opportunities for intensive livestock production.

Vegetables

Vegetable production has significant importance in ensuring food security (both quantity and also dietary (nutrition)) and employment and income options, and as an element of diversification in crop rotation systems. Over the period of 1992-2007, the area cultivated to vegetable crops increased from 609.100 to 739.100 ha, and gross production increased from 8.7 to 14.1 million tons (Source: FAOSTAT, 2008). Average yield has been increased from 14.1 to 18.5 t/ha in 2007 but is 2-3 times lower than the potential. The long vegetative period and the high sums of active temperatures allow raising a wide variety of vegetables, melons and gourds. In the southern zones of the region, cold-tolerant crops, such as cabbage, onions and root crops can be grown all over the year. Tomato and cucumber are basically grown in glass and plastic sheet greenhouses during the winter-spring and autumn-winter periods. Under protected conditions (greenhouse, tunnels, hotbeds), farmers in recent years began to expand diversity, and to raise a cauliflower, pepper, an eggplant and greenery crops.

But still only 15 % of the total production of vegetables is provided to the population in the period November to March. Vegetable production at household level contributes significantly to the supply in rural and urban areas. Especially for poor families, vegetables are among the most accessible food stuffs, and also provide opportunity for extra income. Vegetables also offer more employment opportunities than for instance cereals and by this are favorable crops also for the landless poor.

Table 5: Production of vegetable and melons in CAC

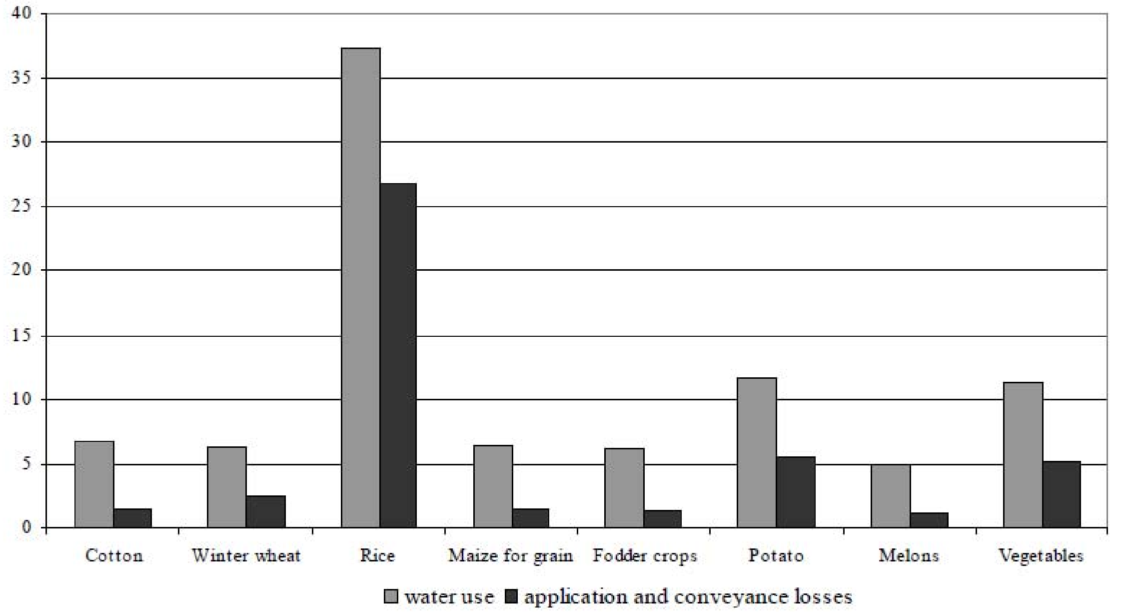
CAC Countries	Vegetable & Melons					
	1992			2007		
	Production, t	Area, ha	Yield, t/ha	Production, t	Area, ha	Yield, t/ha
Armenia	538.800	29.700	18,1	1.051.610	31.935	32,9
Azerbaijan	605.200	40.700	14,9	1.649.543	126.451	13,0
Georgia	330.000	31.000	10,6	263.800	35.700	7,9
Kazakhstan	1.273.500	116.800	10,9	2.858.650	154.540	18,5
Kyrgyzstan	438.705	29.100	15,1	909.072	50.211	18,1
Tajikistan	679.300	36.890	18,4	1.089.270	52.510	20,7
Turkmenistan	493.061	57.731	8,5	757.500	55.800	13,6
Uzbekistan	4.380.700	267.200	16,3	5.510.200	231.950	23,8
Total:	8.739.266	609.121	112.8	14.089.645	739.097	148.5
Average			14,1			18,5

Source: FAOSTAT 2008

In August 2006 the Regional Network for Vegetable Systems Research and Development (CACVEG) was officially founded and works under the leadership of AVRDC (The World Vegetable Center). The CACVEG network aims to assist the development of vegetable production systems oriented to market and trade, and to promote vegetable research strategies for all CAC NARS. The main challenges are weak agricultural management infrastructure, a lack of effective irrigation technology and other modern equipment, few production receiving points and processing facilities and poor seed production and investment deficiency. Although soil and climatic conditions are suitable for many vegetable crops in the region, 60 % of producers grow only few species of vegetables (tomato, water-melon, cabbage and onions). To attain a higher diversity of vegetables, low-cost and resource-saving technologies for production and improved varieties of nutritious species for year-round, safe production are urgently needed. More marketing research is desirable, as they guide farmers and reduce risks of failure and ruin. Marketing research is also necessary to develop the vegetable sector towards cash crop for export within the region, Russia, Europe and Asia (Ali et al., 2006). Further processing of vegetables should be increased, as it opens up jobs in the rural areas and increase income.

With view to climate change, water scarcity vegetables and high value crops specifically melons seem to be more favorable than for instance rice.

Figure 17: Water application and beneficial water use specified by crops



Water application and beneficial water use of different crops, thousand m^3 ha^{-1}

Source: Bobojonov, 2008

Fruits

The region is famous for its fruit crops, the diversity of which is one of the greatest in the world, i.e. apple (*Malus domestica*), apricot (Prunus a*rmeniaca*), peach (Prunus p*ersica*), pear (*Pyrus communis*), plum (*Prunus domestica*), grape (*Vitis vinifera*), almond (*Amygdalus communis*), pistachio (*Pistacia vera*), pomegranate (*Punica granatum*), and fig (*Ficus carica*). Many valuable landraces and old local cultivars of peach, quince, cherry, pomegranate, persimmon and others are still maintained in home gardens and on small farms. Fruits are high value crops – both concerning income and nutrition. Their share within agriculture should be increased.

Table 6: Area of orchards and production of fruits in CAC countries in 2007

CAC countries	Area of orchards, ha	Production of fruits, tons	Yield, tons/ha
Armenia	1600	3800	2.37
Azerbaijan	17419	149992	8.61
Georgia	4000	22100	5.52
Kazakhstan	12000	13600	1.13
Kyrgyzstan	1000	5300	5.3
Tajikistan	7500	13000	1.73
Turkmenistan	n/a	n/a	
Uzbekistan	15000	52500	3.50

Source: FAOSTAT 2008

Herbs, pharmaceutical plants and 'access and benefit sharing'

In 2008, CBD agreed to develop a scheme for fair and equitable sharing of the benefits arising out of the utilization of genetic resources within two years. 'Access and benefit sharing' (ABS) shall be settled at the CBD's 10th Conference of the Parties (COP10) in Japan (2010). ABS shall provide a legal framework for the use of genetic resources for both: the countries, which still host precious biodiversity, and the pharmaceutical research and industry. According to the World Health Organization (WHO), more than 80% of the World population relies in fact on traditional remedies. This is very much true in the CAC region, where medicinal plants are used in almost half of all therapeutic preparations. Recipes on their preparation and use, tested by experienced people, have been passed onto from one generation of healers to another for centuries.

Mountainous regions host a high number of endemic species and CAC is rich in mountain and high mountain ecosystems. Medicinal herbs from high altitude are regarded as more effective and precious than herbs from lowlands by Tibetan Medicine and also by Chinese Medicine. Within ABS herbs and pharmaceutical plants in the mountain regions might develop to become the basis of good income for villagers. But as warming up increases on higher altitude even further than in Central Asia (40 % above global average) this precious heritage is on high risk.

Countless pharmaceutical plants (such as *Mandragora, Achillea, Valeriana*) grow in CAC mountain areas, for instance 800 in Azerbaijan, 750 in Uzbekistan (Kazakhstan: 300, Armenia, Tajikistan and Turkmenistan each 250, Kyrgyzstan 200). Also in the sandy desert areas valuable medicinal species grow, but are little studied. Among them are species of genera Ferula, *Capparis spinosa, Ephedra strobilaceum, reum tataricum, Peganum harmala, Alhagi pseudoalhagi*, numerous species in the genera *Artemisia, Anabasis, Zizifora, Verbascum, Hippophae, Elaeagnus, Glycyrrhiza,* and others (Gintzburger et al., 2003).

Therefore, it might be desirable to increase agricultural research on herbs and pharmaceutical plants in collaboration with Tibetan and Chinese medical experts to get an overview on the variety of species in the mountainous and desert areas in CAC. Research on the effects of climate change on the ecosystems of these plants is necessary. Further research on sustainable collection and cultivation is needed and later trainings. Special sites in the nature have to be protected of any human interference, but ex situ collection is also imperative due to the risk of extinction by higher temperatures. Awareness raising in the villages and collaborative action is necessary for instance concerning pastoralists and unsustainable ways of collection. Agricultural and pharmaceutical institutes in CAC should start research on the effects of herbs and plants. Agricultural and pharmaceutical institutes should urge on legal national frameworks to ensure, that the villages benefit in an adequate way, so that they also can afford to reserve special sites of absolutely protected areas for common welfare.

Sustainable management of herbs and pharmaceutical plants offers also chances to integrate the landless poor in remote areas into CGIAR-activities.

Cotton

Cotton is mainly not a food crop, but is being discussed in this paper for several reasons. First, oil produced from cotton seeds is broadly used for cooking in the region (Rudenko et al. 2008). Second, in vast parts of the CAC region - Uzbekistan, Turkmenistan, Kazakhstan – cotton is one of the dominant crops on irrigated land. Cotton is not only an important cash crop in Central Asia, it is also part of the Central Asian culture and even art. Any policy on food security has to integrate cotton somehow in order to be accepted by the national governments. Hence, discussing cotton is part of the food security strategy.

In comparison to fruits or vegetables and even in comparison to grain, cotton needs less elaborated facilities for storage and transport. Any change towards another staple crop demands trainings, investment in facilities and the establishment of markets for these products. So any change might need assistance both by agricultural research and development aid.

Table 7: Production of Cotton lint in CAC

CAC Countries	Cotton lint					
	1992			2005		
	Production, t	Area, ha	Yield, t/ha	Production, t	Area, ha	Yield, t/ha
Armenia	-	-	-	-	-	-
Azerbaijan	111.000	233.000		55.005,0	112.969	
Georgia	-	-	-	60	100	
Kazakhstan	76.000	111.200		115.000,0	190.000	
Kyrgyzstan	14.000	22.000		48.000,0	45.080	
Tajikistan	174.000	285.300		162.000,0	288.000	
Turkmenistan	390.000	567.000		219.000,0	600.000	
Uzbekistan	1.274.000	1.666.680		1.250.000,0	1.390.000	

Source: FAOSTAT 2006

Table 8: Production of Cotton in CAC

CAC Countries	Cotton					
	1992			2005		
	Production, t	Area, ha	Yield, t/ha	Production, t	Area, ha	Yield, t/ha
Armenia	-	-	-	-	-	-
Azerbaijan	336.364	233.000	1,4	166.681,8	112.969	1,5
Georgia	-	-	-	181,8	100	1,8
Kazakhstan	230.303	111.200	2,1	348.484,8	190.000	1,8
Kyrgyzstan	42.424	22.000	1,9	145.454,5	45.080	3,2
Tajikistan	527.273	285.300	1,8	490.909,1	288.000	1,7
Turkmenistan	1.181.818	567.000	2,1	663.636,4	600.000	1,1
Uzbekistan	3.860.606	1.666.680	2,3	3.787.878,8	1.390.000	2,7

Source: FAOSTAT 2006

There is a lot of room to improve growing of cotton, but there is also a need for targeted strategies for further processing cotton (see below: value chains).

Renewable energy plants

If the energy prices increase significantly, growing renewables for energy production might become economically more attractive, but should be grown on degraded land only, specifically as there are promising sites for wind and solar energy in the region.

Pilot production studies are encouraging and indicate cost effectiveness of up-scaling of grain and juicy stem-sweet sorghum raw material for ethanol production in Central Asia. The area under cultivation of sorghum is still low and income from sorghum is less than from rice or maize, but the sugar-bearing *Sorghum bicolor* is drought-tolerant and can be grown on marginal salt-affected lands with limited irrigation, for instance Karakalpakstan. The traits give benefit and supplement fodder resources to poor farmers in remote desert areas of Central Asia. Sweet sorghum varieties are the most attractive as source for bioethanol. However, state support, strong research and coordination between processing small/large companies, research institutions and farmers should be developed for sorghum breeding, adoption of relevant technologies available for the process of ethanol production in Central Asia. But achievable sugar content, stover and seed yields are still uncertain, and little is known about the incentive structures under which smallholder farmers would grow this plant for smaller/and larger companies, which would make investments in ethanol extraction.

Evaluated sweet sorghum local breeds and ICBA/ICRISAT improved lines attain full milky stage between 81-128 days using limited irrigation (2-3 times per season) of 700-800 m^3 over the season and a plant density of 90-102 thousand ha^{-1}. Mineralization/salinity of irrigation water was around 0.619%. Measurement of plants' height (Figures 2-4) showed that the most intensive growth of the stem started on the 40th day after planting and continued up to the 121st to 145th day after planting irrespective of soil salinity level and variety of sorghum. The first varieties to be harvested were SP-47513, ICSV-112, ICSR-93034, ICSV-707, and GD-65195 as they are considered the fast-ripening varieties among all the tested varieties of sorghum. The top grain yields were achieved with the local variety Uzbekistan-18, which gives 8,9 – 10.6 tons per ha and SP-47513 – 8.7 tons per ha. Varieties S-35, E-36-1, ICSV-707 produced the average yield of 7.66 tons of grain per ha (Toderich et al., 2008).

Stalks for sugar extraction can be harvested 4-5 weeks before seed maturation. In addition, sorghum varieties were analyzed for sugar content at the flowering stage. The highest sugar content of 10 to 15 % was observed for varieties: SP 47513 (15.2%); Orangevoe 160 (12.6%); ICSV 112, ICSV-707 and SP-47529 (about 11%), E -36-1 and S-35 (10%). The highest yield of fresh biomass that produced about 68% of juice and almost 8.5 t ha^{-1} total sugar was obtained for Uzbekistan-18 variety, followed by Karakalpakskiy (6.5 t ha^{-1} total sugar) and Orangevoe 160 (4.1 t ha^{-1} total sugar) as local varieties and Sugar Graze, ICSV 745, ICSV 112 among tested improved lines from ICBA that could successfully used for the ethanol production.

Sweet-stem sorghum has some unique biological capacities, such as to re-grow after mowing and to maintain juiciness of stems and the green color of leaves up to the ripening stage. Abundance of sweet juice in green stems allows preparing fodder of high quality, especially in mixture of sorghum with wild grass like reed, licorice, camel's-thorn, lots of which grow along the riversides and other water bodies of Uzbekistan.

Strategies for meeting the demand in 2050

Tackle weaknesses: crop diseases and pest control

In CAC increased research on pathogens is necessary. Wheat production is under persistent threat from wheat rusts and other foliar diseases, and insect pests such as sunn pest, hessian fly and cereal leaf beetle. There has been frequent occurrence of wheat rusts in CAC region, the most recent examples are yellow rust in Uzbekistan and leaf rust in Tajikistan in 2009. Central Asia also faces potential threat of Ug99 the pathogen was already found in its neighboring country Iran. There is hardly any commercial wheat variety in the region with resistance to all three rusts (leaf, yellow and stem rusts). There are complex interactions among weather variables and pest damage to wheat crop. In a wet wheat season like 2009, yellow rust could become a threat whereas in a dry season foliar blights cause substantial damage to wheat crop. In most CAC countries the wheat crop is protected from diseases and pests largely by spraying chemicals, which increases input costs, thus reducing profitability from wheat cultivation. The extensive use of chemicals has environmental implications as well. In order to improve productivity and profitability of wheat crop and safe guard food security, the above diseases and pests need be managed through resistant varieties and integrated pest management.

Concerning potatoes there are various risks in the CAC, such as Late Blight (*Phytophthora infestans*), Aphids, Ring rot (*Clavibacter michiganensis* subsp. *sepedonicus*) and the fungus *Rhizoctonia solani* Kühn. Late Blight represents a serious threat only in the Caucasus region. The selection of LB resistant clones is, therefore, considered a priority for Armenia, Azerbaijan and Georgia due to the presence of aggressive strains of the fungus (Nogaideli et al., 1991). Georgian scientists estimate that, if Late Blight was controlled effectively and safely through the use of stable resistant varieties, the value of potato production would increase as much as 40-50 percent with a correspondent significant reduction in the use of pesticides. This would lead to increased farmer incomes and reduced environmental risks due to the decreased pollution of groundwater and human exposure to fungicides (Carli, 2008). Among the other diseases affecting potato, viruses represent a serious threat in the whole CAC region, mainly because of the tendency of farmers to use their own saved seed for more generations than it would be recommended. Aphids, the main virus vectors, constitute a serious threat in the plains and in areas where cotton, tobacco, vegetables (especially those that belong to the Solanaceae family such as tomato, aubergine, pepper) and fruit trees of the Prunus spp. (peach, apricot, plum, cherry, almond), hosts of the green peach aphid or *Myzus persicae*, are intensively cultivated (Carli et al., 2008). Breeders and virologists at CIP are working to incorporate virus resistance into new varieties.

As potato produces a lot of flowers and thus attracts many beneficial insects, especially those that belong to Hymenoptera family. At flowering stage application of insecticides containing imidacloprid (Gaucho, Confidor, Prestige, etc.) should be avoided due to their harmful effect on bee population (Baltaev et al., 2008).

Still agrochemicals are broadly used for food production. Since 1990 in Central Asia all pesticides estimated by Stockholm Convention as persistant organic pollutants are forbidden, but they are still used. For instance in Tajikistan two polygons[15] for bearing of hazardous pesticides still exist and bear risks for Syr Darya (Boltaev, 2005). In Kazakhstan and Kyrgyzstan these hazardous pesticides can still be kept in storages and might be used (Mustafina, 2005, Khodjamberdieva, 2006). In 2005 ecologists from Central Asian countries urged the governments to control farmers' use of pesticides (Kohdjamberdieva, 2006). The problem was also discussed by the Tajik National Coordinating Board on conditions of Stockholm Convention (Juraev, 2006).

Whereas agrochemicals are prevalent for wheat crops and vegetables, Integrated Pest Management (IPM) has a long tradition in Central Asia. In the 1970-1980s IPM programs were introduced to cotton fields and hundreds of biological laboratories were established for mass rearing the parasitoid *Trichogramma, bracon and* predator *lacewing* (Rashidov, 2001). At present in Uzbekistan, about 1000 biolaboratories exist, which produce beneficial insects intended for control first of all insect pests of *Noctuidae* family (bollworm, armyworm, turnip moth, curworm etc). In Kyrgyzstan, six biolaboratories are known to produce entomophages of crop pests. Also in Tajikistan some biolaboratories remained . The present status of biolaboratories in Kazakhstan is unknown (Alimukhamedov et al., 1991). But these achievements concern primarily cotton.

Various pests develop and spread over Central Asia, while the areas for wheat and vegetable crops including greenhouse crops increase. Diseases, pests and weeds can cause up to 30% yield loss on vegetable and wheat crops (Nabiev, 2007). Currently the main key pests on vegetable crops in Central Asia are: phitophtora, top rots and various virus diseases; bollworm and such sucking pests as mites, aphids and whiteflies; various numbers of weeds, including the parasitic plant broomrape cause significant economic risks. Global climate change fuels the spread of these pests according to Turdukulova (2006).

Various species of *Noctuidae* family on vegetables can be controlled by biological methods (Rashidov, 2008). But chemical control still prevails specifically against sucking pests in nightshade crop protection. At present there are conferences, seminars, workshops and trainings on IPM, which offer biological control, physical control, cover crops, microbial agents, plant resistance, crop rotation, beneficial insect conservation by using nectar plants (landscape ecology) and others.

[15] Sites for graving harzardous chemicals

Tackle weaknesses: water and soil productivity

The irrigated land in Central Asia has been expanded from 4.5 million ha (1960) to 7.9 million ha today, but at the same time the amount of water, the farmer could expect shrank, which causes higher risk of crop failure (Martius et al., 2008). Uzbekistan still plans to expand the area for irrigated agriculture, though already now marginal land is used as well. The irrigation systems have already been partly dysfunctional, when the Central Asian countries declared their independence. The drying up of Aral Sea (to 15 % per volume and 35 % per surface) is a consequence of water mismanagement, not of a lack of water in the region (Martius et al., 2008). 83 % of the water in the Amu Darya basin is used by Uzbekistan and Turkmenistan. Turkmenistan has built a channel to convey water around Khorezm and Dashoguz; according to Giese et al. (2004) up to 80 % of the water is lost due to poor infrastructure. Turkmenistan (5324 m^3a^{-1}), Kazakhstan (2351 m^3a^{-1}) and Uzbekistan (2292 m^3a^{-1}) consume much more water per capita than Egypt (977 m^3a^{-1}), China (485 m^3a^{-1}) or Morocco (172 m^3a^{-1}) with extremely low productivity (UNDP, CARRA 2009a).

Most of the water in CAC is used by agriculture, but inefficiently, mainly due to lack of knowledge and resources for farmers. Major deficiencies are: insufficiently leveled land; excessive plot size and furrow length with corresponding over-watering and seepage at the head and under watering at the tail end; and insufficient attention to correct crop water requirements as well as soil water retention capacity. In Central Asian countries, the available information associated with crop water requirements has very little relevance with current day challenges of water scarcity and environmentally sound water use. There is a critical need to update this information on the basis of soil, crop and climatic conditions for different agro-ecological zones. Absence of water accounting at farm gates, unstable water supply to farms, discrepancy between planned irrigation modes and required ones and absence of plan schedule of water use are further reasons for low water and crop productivity. Preliminary results of a IWMI-research suggest that water productivity is less than 0.3 kg of raw cotton or 0.9 kg wheat grain per m^3 of irrigation water under excessive water conditions in some parts of the Fergana region while others are stressed by water shortage. Over 30,000 ha of agricultural land of Mirzachul steppe are abandoned due to a lack of irrigation water and consequent salinization (Kushiev et al., 2005). Farmers on over 900,000 ha of land of middle stream of Syr Darya river receive water for 1-2 irrigations of cotton, which causes low yields not exceeding 2 t/ha. Upstream regions have issues related to excessive water use causing water logging and salinity, farmers of lower reaches do not have access to water that result in thousands of ha being taken out of cultivation. As irrigated land became saline within the decades of cotton monoculture, farms spend a lot of water on leaching the fields. Often they reduce the outflow of the drainage channels in order to ensure that their own fields will have enough water in weeks of water scarcity. But as this practice causes high groundwater tables and soil salinity, it often results in more leaching (Martius et al., 2008).

Biomass production in dry areas is limited, but even small amounts of residue retention can significantly decrease soil erosion losses (Thomas, 2008). Numerous technologies, practices and strategies have been developed to increase water use efficiency in agriculture in the region. They could potentially be used within adaptation programs in agriculture. Dissemination of modern technologies is low. For instance alternate furrow irrigation (AFI) has been adopted by many innovative farmers in different parts of the CAC, but with view to the total of farmers these alternative furrow irrigation is still rarely used. The technology has proved successful on moderate and heavy loam soils. The yield of raw cotton was increased using cutback and discrete methods of irrigation by 10% and 8%, respectively, compared to the control. On average, surface runoff was reduced by 34% and deep percolation by 14% using cutback and discrete AFI. AFI increased water productivity by 8-57%. Reduction of physical evaporation from the soil surface contributed to increase of water productivity. Although average water productivity under AFI was increased by 32%, the water productivity values remained below 0.5 kg/m^3 which suggest the need for integrated water/soil/crop management. Micro-furrow irrigation technology increased soil moisture from 0.7 to 0.85 of field capacity and reduced surface runoff from 5–50% to 2–20% in field experiments in Tajikistan (Thomas, 2008). As irrigation has to be improved nearly everywhere, these low cost technologies seem to be favorable in comparison to drip irrigation. The often repeated request for drip irrigation on fields should be used as an argument to shift towards higher income crops like vegetables, melons and fruits with view to cost effectiveness.

Research in the Jizzak region and Pakhtakor has shown that raised-bed planting of wheat and rice improves both the yield (6.0 to 6.5 t/ha and up to 14.2 %, respectively), and the water productivity (from 1.23 t/1000 m^3 to 1.32 t/1000 m^3). At the same time the seed rate is reduced by 100 kg seed/ha. Farmers planting wheat under irrigation on permanent raised beds in 13 case studies around the world achieved on average 7.7% higher yields, while saving 25-35% water (Sayre et al., 2004). In a 5-year experiment, farmers had on average 27% higher wheat and 48% higher maize yields under rainfed conservation agriculture than with conventional tillage (Govaerts et. al., 2005). Furthermore, Erenstein et al. (2007) estimated that farmers save 15-16% on operational costs; and even if yields are lower, the cost saving effects translates into higher income per hectare (Erenstein et al., 2008). Leaving residue on the field is critical for zero tillage practices. However, it can take some time—roughly 5 years—before the benefits are evident. In irrigated wheat fields in Central Asia, although there was no change in yields from conventional tillage to permanent bed, operational cost savings made the permanent bed system superior to all other systems (including zero-tillage) (Tursunov, 2009).

Intercropping often provides better income and improves the soil quality at the same time. Intercropping of maize and mung beans for instance improved the net profit of the farmers by 550 UDS/ha in Pakhtakor, intercropping of cotton and mung bean increased the net profit by 650-850 USD/ha (ICARDA-SLMR Project 2009). - Application of crop residues (mulch) to cotton and winter wheat in Khorezm increases the soil organic matter (SOM) content from 0.53 to 0.80 % in four years. The mulch cover also significantly reduces soil evaporation and thus decreases the increase in soil salinity. In winter wheat in Kushmanata the mulch application reduces the increase in soil salinity by 17 % (ICARDA-SLMR Project 2009).

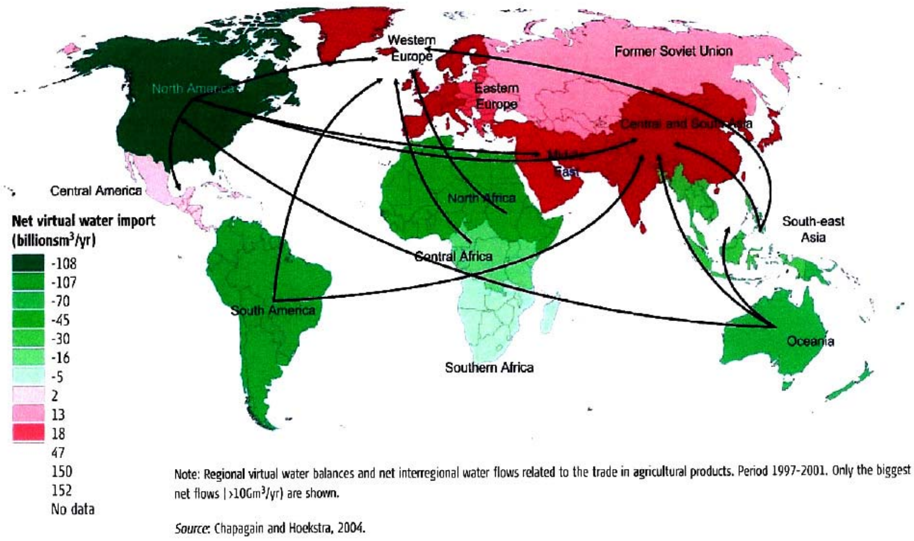
Various such options have been developed, for instance water harvesting (Oweis *et al.*, 1999; Fleskens *et al.*, 2007), improved management of return waters (Dukhovny et al.,, 2001)**,** use of waste and drain waters (Karadji *et al.*, 2002; Mamatov, 2002a, 2002b, Toderich et al., 2009), drip irrigation (Palvanov, 2002), sprinkler irrigation (Maltsev, 2002), use of zigzag furrows (Kambarov, 2003), sub-irrigation with groundwaters (Mirzadjanov, 2003), supplemental irrigation (Sanginov *et al.*, 2005), domestication and cultivation of halophytic and drought resistant crops in saline areas (Toderich *et al.*, 2008; Kushiev *et al.*, 2005), laser land leveling (Abdullaev *et al.,* 2007; Egamberdiev *et al.*, 2008), afforestation of degraded croplands (Khamzina *et al.,* 2008; Lamers et al., 2008; Toderich et al., 2009), bio-drainage (Aliev *et al.*, 2005), various crop diversification and conservation agriculture practices (ICARDA-CAC, 2007), or at the institutional level, applying the principles of integrated water resource management (IWRM) in whole watersheds or irrigation basins (Abdullaev, et al., 2009). For instance by using laser-guided land-leveling 15-20 % less water is needed during leaching and irrigation, according to field research in Khorezm and Jizzak. Water associations might identify the provision and renting of the equipment as an additional activity. The apparatus costs about 5000 $ each and it takes one hour to screen a field of 100x100 m (ICARDA-SLMR Project 2009).

Awareness-raising for virtual water

Worldwide 70 % of freshwater is used for agricultural irrigation. Within the CAC there is not yet a discussion on virtual water or on the water-footprint of products, though most agricultural products of the region have a high water-footprint due to the crops and due to the way, they are grown (see also: figure 17).

When UNDP focused on increasing water efficiency and water productivity 23 July 2009 in Tashkent, not only the Deputy Minister for Agriculture and Water Ressources, but even the directors of NARS protested and tried to turn UNDP towards advocacy for a higher share of water from trans-boundary rivers for Uzbekistan. The readiness to realize that there is a reasonable amount of water in the region, that scarcity is man-made due to choice of crops, techniques and underdeveloped processing facilities for raw products is quite low in Central Asia. At present in the region the relevant stakeholders even in NARS apparently do not realize that Uzbekistan is – as Turkmenistan and Kazakhstan - a net exporter of virtual water and might produce agricultural crops by much lesser water costs.

Figure 18: Global flow of virtual water



Source: Chapagain and Hoekstra, 2004, cited by Grohmann 2008

The water-footprint of products can be significantly reduced by better management. The amount of water to grow cotton ranges between 3.6 and 29 m^3/kg (Paulitsch et al., 2004, cited by Partzsch). For the production of 1 kg cheese 5 m^3 water are needed, for 1 kg beef 16 m^3 (UNESCO 2006, cited by Partzsch). To produce 1 kg of irrigated wheat takes an average of about 1 000 to 2 000 liters of water, 13000 to 15000 liters are necessary to produce the same quantity of grain-fed beef. "*Thus, each human being "eats" an average of 2 000 litres of water a day*" (FAO, 2008a). Also the pollution of water (and soil) caused by different products has to be taken into consideration. The water-footprint of agriculture can be significantly reduced by more sustainable land management, by change of crops and often by developing value chains for raw products. High water prices urge farmers to invest in better irrigation techniques or other crops, higher water prices would also stimulate the development of processing industry. This would match with the User-Pays-Principle, which gets into force step by step mostly driven by OECD, EU and UN. According to this principle also the consumers of food, T-Shirts and other products should pay higher prices, which reflect the water-footprint of products.

As consumers demand more and more eco-labeled products, research on and advocacy on labeling cotton and cotton products seems to be desirable. In Germany there is even a big mail-order firm with high reputation specialized on eco-labeled cotton (OTTO[16]). The topic of environmentally fair prices is also discussed on UN-level, for instance within the Marrakech-process[17] on sustainable consumption and production (SCP) and the International Conference on Water and Environment (ICWE). GGIAR might get deeper involved in this discussion.

In some areas like Karakalpakstan (Uzbekistan) and other downstream areas of the Aral Sea Basin (Martius et al. 2009) the high water consumption by agriculture causes water stress for residents in terms of quantity and quality. And although freshwater is not subject of this paper, freshwater has to be regarded as the most important food at all. In Bolivia, India and elsewhere freshwater scarcity already caused riots and conflicts.

Establishing value chains

The development of value chains is highly desirable, because they provide income and jobs while reducing the demand for land and resources at the same time, as Rudenko et al. show on the example of cotton (Rudenko et al., 2008). Further processing cotton would increase the income per ha for cotton and probably even more jobs the higher the processing is. A value chain analysis developed by economists (ZEF/UNESCO) in the Khorezm region (Uzbekistan) shows that with the involvement of the local textile enterprises in processing cotton fibre into cotton yarn, already the same regional export revenue could be achieved while reducing 30.000 ha sown to cotton (roughly 27 % of the current area). 228 mln m^3 of irrigation water could be saved, and about 6 mln USD in explicit subsidies removed. The further the processing within the country is, the higher the income, the lesser the stress on the environment.

Table 9: Value chain for cotton (Khorezm, Uzbekistan)

	Required raw cotton, thousand tons	Required cotton area, thousand ha	Reduction in cotton area, %	Irrigation water on field level, mln. cub.m.	Explicit subsidies to agriculture, million USD
Baseline (2005)	287	110	0	824	20
100% fibre export	239	92	17	688	17
Increased ginning efficiency	219	84	23	631	16
Yarn export	207	79	28	596	14
Fabrics export	173	67	39	499	12
T-shirt export	89	34	69	257	6

Source: Rudenko et al., Wert schöpfen, Wasser sparen, Effizienzsteigerung im usbekischen Wassersektor, in: Osteuropa 58/H.4 (2008)

Value chains require not only the existence of relevant factories, but as well the establishment of an "operating environment, which sets the conditions for chains to operate and interact among

[16] In 2002 the mail-order firm introduced the quality label PURE WEAR for clothes and textiles produced from organic cotton. OTTO is one of the world leading processing companies for organic cotton (for instance in 2001 533 t organic cotton has been processed). OTTO does not produce expensive clothes for the upper class, but clothes for everyone, also for the poor strata.

[17] In 2002 WSSD started a ten-years-program for SCP, called "Marrakech-process", to decrease the ecologic footprint of products by 3R-strategy (re-use, re-duce, re-cycle) and to give impulses to change consumption patterns. *www.unep.fr/scp/marrakech/*

stakeholders" (Rudenko et al., 2008). These value chains might be also effective for fruits and vegetables, Karakul sheep pelts (one of the major sources of income in Kyzylkum Desert and one of the main export goods in Uzbekistan) for wool and pharmaceutical plants. For instance Karakul sheep pelts: More than 30 colorations have been developed by breeding. Designing and tailoring clothes doesn't take place in the CAC, the pelts is exported mostly to Russia, so that the chances for employment and income are not yet effectively used. According to the Uzbek Research Institute of Karakul Sheep Breeding and Ecology of Deserts (April 2009) there is not even a research on a value chain.

The development of value chains seems to be a promising strategy to achieve food security in the CAC, specifically for those countries, which have little arable land per capita.

Underutilized plants

IAASTD explicitly recommended to "include developing high-value and underutilized crops in rain fed areas; increasing the full range of agricultural exports and imports, including organic and fair trade products" (IAASTD 2009a).

Within different regional research some crops have been identified, which might be favorable also for other regions with view to increasing climate change. Kohlschmitt et al. (2007) identified for instance gooseberry, sour cherry, pistachio, jujube date, fig, almond, barley, topinambur, safflower and tobacco as plants with good future prospects in Khorezm also for export to Europe. Due to similar agro-climatic conditions these plants might be favorable also in Karakalpakstan, the northern part of Turkmenistan and the southern part of Kazakhstan.

Bedoshvili et al. (2009) identified berries, subtropical fruits (kiwifruit, feijoa, persimmon, etc.), cabbages and topinambur as most promising alternatives in subtropical West-Georgia, specifically with view to the European market. There should be further research, most of them, except the berries, might be favorable also in South East Azerbaijan (Lenkorian).

Sorghum and pearl millet can stand salinity better than maize, sorghum can also withstand pH levels up to 8.5 (Rehm et al., 1991, Massino, 2005), whereas maize is not drought tolerant. Sorghum is the most drought resistant crop and can be cultivated with lower irrigation/rainfall levels than maize (Rehm et. al., 1991). Water efficient, drought-tolerant and salinity-tolerant crops such as sorghum, pearl millet, barley, safflower, amaranthus, triticale and licorice have a potential as fodder-crops and provide good income chances for farmers for instance in saline sandy desert and longtime irrigated areas, while simultaneously improving the soil quality.

As the demand for healthy - for instance gluten free - cereals increases in Europe and the US (Sands et al., 2009; Morris et al., 2006), more focus on nutrition than on yield might provide also better income than the wheat produced at present. This is a challenge for breeding – but as well for introducing old crops which are just not grown in CAC, like Teff (Eragrostis tef). Teff, quite common in Ethopia and Eritrea and recently also grown in the Netherlands (on the basis of a formal ABS-agreement with Ethopia), is rich in iron and does not contain gluten. Meantime teff is also popular in Germany.

In the Kanimekh district (Navoi region, Uzbekistan) ICBA in collaboration with the Uzbek Research Institute of Karakul Sheep Breeding and Ecology of Deserts identified key species for rangeland rehabilitation such as Haloxylon aphyllum, Kochia scoparia (L.), K. prostrata, Eurotia eversmanniana, annual and perennial species of Salsola, Climacoptera lanata, Glychyrryza glabra, halothamnus subaphyla, Agropyron desertorum, Atriplex nitens and A. canescens . These species might be used for the re-seeding of degraded pastures both in pure or mixed stands by increasing the productivity of rangelands more than 1,8 -2,5 times, thus to prevent food shortages for all kind of animals in the course of climate change (Toderich et al., 2009). Many of the above noted species might offer also good alternatives for rangelands improvement in Kazakhstan, Tajikistan and Kyrgyzstan.

Afforestation offers several chances simultaneously. In Uzbekistan for instance 5-10 % of degraded cropland areas are potentially suitable for afforestation via CDM (around 215-430.000 ha). Research in Khorezm has shown that in the fifth year after afforestation the C stock in Russian olive (Elaeagnus angustifolia L.), Siberian elm (Ulmus pumila L.) and Euphrates poplar (Populus euphratica Oliv.) is about 20 t/ha C in the woody biomass. In the upper 0.4m topsoil layer SOM content increased by 20 % within five years after planting (8 t/ha). Afforestation with such tree species provides also fuel wood of high calorific value and energy value to cover the needs of the rural population (one ha of trees grown over 5 years could cover the average annual per capita need of 55-89 people). In addition tree plantations provide leaf fodder and fruits while reducing wind erosion and soil salinity. They even enrich the soil. These trees might be favorable also on degraded cropland in Karakalpakstan, the northern part of Turkmenistan and the southern part of Kazakhstan.

An agro-silvicultural model of trees intercropped with complementary crops was evaluated by ICBA on marginal lands at Akdepe (Turkmenistan) and Kyzylkesek (Uzbekistan) sites. Herbaceous fodder crops planted within the inter-spaces of salt-tolerant trees/shrubs plantations improve productivity of saline prone soils, solve the animal feed gaps in the lands degraded both by overgrazing and salinity and increase the profits for farmers. Wild halophytes planted in widely spaced patterns allows for easy mechanical cultivation and harvesting of forage grass and legumes. ICBA and NARS screened various trees and shrubs and identified 16 multipurpose tree species (MTS) showing high survival rate, quick relative growth rate, high adaptive features and utility value of firewood and/or foliage. The most promising trees were Haloxylon aphyllum, Populus euphratica, P.pruinosus, P.nigra var.pyramidalis, Elaeagnus angustifolia, Robinia pseudoacacia, Tamarix hispida, T. androsowii, Salix babylonica, Cynadon oblonga, Armeniaca vulgare, Malus silvestris, Acacia ampliceps. Among the shrubs the most promising werde: Atriplex canescens, A. nitens, and A. undulata, Hippophae ramnoides and Ribes niger including native rangelands halophytes alone, or mixed with various traditional salt tolerant fodder crops. Trees/shrubs plantation requires limited irrigation during the initial stage of growth before sole reliance on available drain water (Ec ≈ 4.0 -6, 3 dS m^{-1}) resources become possible. Species of Tamarix, Elaeagnus and Salix having an exceptional ion-salt translocation/bio-remediation mechanism are often referred to as aggressive colonizers since they tend to invade natural habitats and push out less salt tolerant species. E. angustifolia, Morus alba, M. nigra, Acacia ampliceps and Atriplex species offer possibilities as supplementary feed to the low-quality roughages throughout the off-season.

The expansion and commercialization of non-timber forest products has the potential to increase the cash income of rural households, if the forests are sustainably managed. Specifically the large walnut (Juglans regia) forests in Kyrgyzstan have a high potential and require urgently protection for sustainable use – for instance by the Forest Stewardship Council (FSC)[18].

Further research is needed to identify more favorable – sometimes even dual-use - plants, which are underutilized or unsustainably utilized, but have great potential with view to climate change, for instance sea buckthorn (Hippophae ramnoides L.), mulberry tree (Morus alba, M. nigra), Russian olive tree (Elaeagnus angustifilia, species of genus Berberis, black carrant (Ribes nigrum L.) or Ferula assafoetida.

[18] www.fsc.org; One year after the UN world conference in Rio (1992) FSC was founded 1993. Internationally FSC is regarded as the most advanced label for sustainable forrest management. It combines environmental, economic and social aspects, external monitoring and includes non-timber products. FSC is well known in Europe and meantime various companies sell only FSC-labeled wood products.

Ferula assafoetia provides fodder, culinary spices, medicinal values (alterative, antiperiodic, antispasmodic, cardiotonic, carminative, deobstruent, deodorant, expectorant, laxative, parasiticide, sedative, stimulant, tonic) and flavor for perfumery (Brown, 1995). This plant has very deep root system, can be cultivated in light sandy to heavy clay soils, can tolerate -10 to 50°C temperature and substantial level of soil salinity (Huxley, 1992). It is freely growing in large abandoned lands (due to high salinity) and semi-desert areas in wild forms in many Central Asian countries. Commercial cultivation of this plant can contribute significantly for environmental protection and sustaining the livelihoods of the inhabitants.

The largest representative, by the number of species and by the propagation areal, of barberry family is genus Berberis, an evergreen or deciduous bush, sometimes it grows as small trees. Out of eight species of this plant, growing in Central Asia, about five barberry species are described in Uzbekistan. In Zarafshan valley (Uzbekistan) three species are found – B. oblonda (Rgl.) Schneid., B. integerrima Bgl., B.nummularia Bg. They are widely distributed on rocky and rubbly slopes and valleys of streams and in the belt in upper and middle flow of Zarafshan river. From ancient times, barberry has been used as decorative and fruit-bearing plant, and as medicinal raw-material. In fruiting period of the plant, vitamin E and ether oil appears in leaves. Fruits contain up to 6% of apple acid and up to 104 mg of vitamin C. Medicinal property of the plant is defined, mostly, by berberin alkoloid. Also, barberry preparations are used as blood-clotting agent during internal and urethral bleedings, for treatment of liver, gall-bladder diseases, as well as intestine toning and appetite rising agent. Barberry was also used for malaria treatment. Barberry fruits were used as food product in fresh and conserved form (jam, jelly, syrups).

Sea buckthorn (Hippophae ramnoides L.) is indigenous in nearly all CAC-countries and has rich intra-specific diversity (Kabulova et. al., 2004, Kabulova et al., 2005, Kabulova et al., 2007). Sea buckthorn is a fast growing plant (either tree or shrub) with a lot of deep roots (up to 5m). Thus the trees keep the soil in and along riverbeds, which are at risk by melting glaciers, and mountainous areas threatened by desertification. The tree provides good firewood and the fruits contain a lot of Vitamin C and can be processed to juice, jelly and sweets. The trester can be pressed to produce oil. Both, for the oil (cosmetics, pharmacy) and for juice, jelly and sweets there is high demand in Europe. - Sea buckthorn also plays an important role in the ecosystem of tugay forests as one of the main sources of food for birds and animals. Kabulova recommends to introduce Sea buckthorn in commercial fruit growing. (Kabulova et al., 2007).

Degraded saline land – a promising area also for forage production?

More diversification of crops and involvement of multi-purpose plants are necessary to cope with climate change and the growing demand for food in the region. More research is needed for the reclamation and sustainable use of marginal and saline lands. As agriculture nowadays is mainly carried out by smallholder farmers, national action plans need to address the farmers and agropastoralists as main land users, in order to show the feasibility of the biosaline technologies, allow for technology adoption in a participatory process, raise awareness and provide information for the regional out-scaling of the successful measures.

Degraded saline areas including halophytic plant resources have a huge potential to serve as crop and forage and pasture improvement (Mainguet et al., 2002, Gintzburger et al., 2003, Toderich et al., 2009). Today the non-conventional methods have to be devised to study and use the desert rangelands economically, and halophytes might permit such utilization, if the areas are properly characterized and managed. The use of halophytes as indicators of soil physical and chemical properties could be an effective and useful method to facilitate the transfer of information about these lands from laboratories to the end users. Soil-vegetation relationship of saline localities has been documented in literature (Aparin *et al*., 2006, Toderich *et al*., 2009). Land and water management is critical in order to reclaim saline-sodic soils and vegetative bioremediation or restoration of saline land through re-vegetation is a new strategy for the reclamation of salt prone soils (Qadir et al., 2007). This management could be even more useful because a number of halophytes can be utilized as raw resources for forage, food, energy-crops, edible oil, fiber materials, traditional medicines etc. Considerable research has been done on soil-vegetation relationship in coastal marshes saline soils (Toft *et al.*, 2002, Khan et al., 2003, 2007). However, investigations identifying the major environmental factors associated with vegetation patterns on inland saline desert areas are scarce and limited to the descriptive botanic documentation of species. Previous studies have shown that many wild halophytes grow well in association with a variety of salt tolerant traditional crops and often provide severe competition to tree/shrubs species, both in natural and improved pastures both on saline and disturbed mine sites (Toderich *et al.*, 2007, 2008, Aralova et al., 2009 submitted).

Encouragement is needed for sustainable development of saline/sandy deserts soils by mobilization of phytogenetic resources, involving both native and introduced salt tolerant plants. Studies are desirable on their ecological, morphological and structural-functional properties, seed and biomass production, low-cost technologies to optimize the selection and domestication of halophytic arid plants. In addition, it would have a significant goal for salinity control, remediation and economic development of arid/saline lands. One of the most promising uses of halophytes will be the production and conservation of important seeds germplasm. The demand for seeds of salt-tolerant species has increased and a number of farmers have become interested to apply biosaline agriculture techniques as a feasible option for their marginalized farms. An innovative selection programs and development of suitable modern agro-technologies are needed to multiply seeds and/or salt tolerant plant material, establish them within natural plant communities and introduce them where they are suitable in different ecosystems.

An integrated Biosaline Agriculture Program for sustainable and integrated use of marginal mineralized water and salt-affected soils for food-feed crops and forage legumes might improve food security, alleviate poverty and enhance ecosystem health in smallholder crop-livestock systems has been developed for Central Asian countries. Furthermore, the activities proposed here will also contribute to C sequestration by large scale biomass production which, through leaf litter fall, will build up soil organic matter. It will thus, also contribute to make the poor farmers more resilient against climate change (Toderich et al., 2009).

5. Recommendations

What single countries should do

- Develop their individual food security policies on the basis of the forecasted figures for 2025 and 2050 (population and food demand, land degradation and desertification, climate change, water and arable land per capita). CGIAR might help preparing papers for integrated food security strategies as a basis for further discussion in the countries. Those papers would need to be wide-ranging and address also aspects not directly belonging to food security, such as consumption patterns, education, reproductive health, conflict scenarios, new, internationally discussed taxes and charges (such as water prices for the agricultural sector CO2-tax, internalization of environmental costs into product price, etc.).
- Rapidly intensify research on intensification of food production with view to the high population growth and limited arable land in Central Asia. Higher yielding varieties need to be bred for the saline, water-scarce, drought-prone areas; land management must be technologically improved (better machinery, technologies, rotations and intercropping, better land management skills,

seconded by land reforms where needed). However, breeding at best produces a 3% increase in productivity per year, while proper land management is likely to increase productivity by 20-30%. The productivity of land, water and inputs needs to be increased. Here is a clear area of input for the CGIAR in collaboration with NARS.

- In view of the same and regarding different social groups, start or increase further research on pros and cons of strategies focusing on food independence or on export/import. In general the latter might be favorable in Caucasus and Central Asia, but may not be politically feasible. With view to disasters caused by climate change subsistence farming must be encouraged as a buffer against food insecurity in remote rural areas where transport costs are high.
- Advocate for and assist the development of national adaptation strategies on climate change. Such strategies should follow an integrated approach developed from the macropolicy view, to improve agricultural methods, to increase the variety of crops and to grow cotton in more sustainable ways. They should also promote broad awareness raising on different aspects of agriculture. Increased dialogue with the governments and NARS on the research-demands caused by climate change seems to be highly necessary. Start a broad awareness campaign on the ecological footprint of products – including involvement of the public/NGO.
- Encourage risk prevention by adaptation measures and support networks of mountain and remote desert villages by research and agricultural trainings. Include development of regime of grazing and rotations of pastures, provision of land and animals, reforestation and research on grass, grain, fruits vegetables, herbs and pharmaceutical plants for changing climatic conditions in high altitudes and in the desert areas. Gender awareness is needed.
- Tackle the lack of dissemination. With regard to the rapidness of climate change in CAC agricultural research and the educational sector (including the public/NGO, media) should work closely together to raise awareness and knowledge concerning future scenarios in order to create more pressure on decision makers. In all countries of CAC region the Ministries for Agriculture and Water Management should promote more actively the quick and broad use of research results in the daily practice on farmland (e.g. diversifying the current cropping system, mulching and laser-guided land-leveling), give guidelines for afforestation of degraded marginal lands, intensify research on heat and drought resilient vegetables and fruits and develop the export of these cash crops. Create a system of competition concerning broad use of new knowledge. Choose multipliers from different areas for trainings. Develop more intensive training, using more result-oriented training methods would be favorable. Participation of women should be increased. Prepare more handouts.
- Develop and implement integrated and well funded national PGR strategies. Focus more on strategic (multifunctional) plants for each country. Include more focus on PGR of underutilized plants, which are used by the poor or which might be of high value within an established ABS-regime. Concentrate more on herbs and medicinal plants on high altitudes. Protect and re-establish shrubs and trees for pollinators and birds close to the fields. Develop protection strategies for the biodiversity of pollinators. Intensify IPM for food crops and further reduce the use of agrochemicals.
- Grow bioeenergy only on degraded and marginal lands. Bioenergy should not compete with food.
- Develop market chains by increasing investments in agro processing facilities and easing trading and marketing conditions including expanding market information systems for entrepreneurs.

What needs to be addressed regionally, within CAC

- Prevent conflicts by high migration. If the next generation of rural inhabitants cannot make their income in agriculture, a high number of young women and men might migrate to urban areas. To integrate them might create an even bigger challenge for the governments than providing food security by purchasing food from the world market. “Social and political stability” might be used as

an argument to convince the governments in CAC region, to adjust their agricultural performance. Specifically in countries where agriculture plays a minor role concerning GDP, social stability is an important argument.
Stimulate social research on stereotypes and concepts of an enemy as climate change and chronic food insecurity are likely to cause social disasters and violence along ethnic borders.

- Improve agricultural research in CAC: Strengthening the network of scientists to attract funding and facilitate information exchange within CAC would not even require better language skills. Recommend the provision of intensive English language courses by the countries. Support capacity building and involving more young specialists for researches. Support upgrading research facilities. Without better interaction with the international community NARS cannot keep abreast with current developments. International partnerships of agricultural research sites (universities and institutes) between OECD-member states and countries in the CAC might be an instrument, to improve the level of researchers in CAC and to establish ongoing contacts.
- Increase the product exchange between CAC countries towards a free market zone CAC. A better developed market infrastructure could help to stabilize commodity prices in these countries and obtain food security under climate change. The agricultural sector in all CAC countries, the consumers and the ecosystems would thus benefit.
- Change the approach concerning better management of trans-boundary rivers with the help of the vision of DESERTEC-CA (see above) to reduce the need to extend hydropower in Kyrgyzstan and Tajikistan and to reserve water for agriculture.

Increase focus on food security and climate change on UN-level

- Use Stern-Review and WBGU (both regard Central Asia as a region with high risk of conflicts) as strong arguments to increase multilateral support for CAC in general and specifically in water management and agriculture.
- Increase the focus on food security within the multilateral dialogue on climate change. Within the Kyoto process, food security does not play an adequate role yet. Urge on coverage and offer research input and intensified cooperation.
- Use the risk of food insecurity caused by climate change and the related risks of conflicts as an argument to speed up mitigation within the Kyoto/Kopenhagen-process.
- With view to the Polluter/User-Pays-Principle and the various drivers of global warming (energy sector, transport, housing, consumption, deforestation, agriculture etc.) develop a policy paper on contributions to agricultural research on adaptation either within or apart the already existing flexible instruments of the Kyoto-Protocol. Concerning forests the discussion is already in process[19], but concentrated on mitigation. In 2006 the Conference of the Parties (COP) created a window of opportunity by adopting the Nairobi Work Programme on Impacts, Vulnerability and Adaptation to Climate Change (NWP). NWP is focused on adaptation efforts and should help countries to improve their understanding of climate change impacts and their risk exposure. As NWP is designed to increase the countries' ability to make informed decisions on how to adapt successfully, agricultural research should benefit from NWP.
- Actively contribute to the multilateral discussion on acknowledging refugees due to environmental degradation and disasters as refugees, who are entitled to protection by the UN. CGIAR - as an expert on agricultural areas and the risks caused by climate change – has important arguments on this issue.

[19] www.undp.org/mdtf/UN-**REDD**/overview.shtml; *unfccc.int/methods_science/**redd**/items/4531.php*

- Use the argument of sustainable agriculture becoming more and more an instrument of keeping peace – but without access to the huge funds of so called UN peace keeping.

Actions at the OECD/UNECE-level

- Both organizations prepare Environmental Performance Reports (EPR). These include around 50 recommendations, which are accepted by the national governments; there is a follow-up after 8-10 years. But within the chapters on biodiversity the biodiversity of agro plants is not yet covered. Agriculture mostly plays a minor role within these reports. Often there is no special chapter at all. Until now the chapters on agriculture do not have a view to climate change, agricultural research is not even mentioned (except Uzbekistan/2009 - UNECE). Some of these reports are done on countries, which have a strong agricultural sector (as USA or Australia). Some of the countries are in dry areas, they have good research capacities and funds to invest in research. OECD decided in February 2009, to derive the next cycle of EPRs more from future-forecasts. Therefore, contacts to both organizations should be used, to broaden the review topics and to integrate sustainable agriculture with view to climate change as an obligatory topic specifically in dry areas. Funds for agricultural research must increase also on the national level.

Within the CGIAR

- Adjust the performance of CGIAR with view to the mandate. CGIAR has the mandate to contribute to the improvement of living conditions of the poor by agricultural research. Further research projects should include components for the benefit of the poorest of the poor, living in rural areas without access to land and animals. Climate change will cause an increase in number and vulnerability of these groups and agricultural research should identify strategies to get these groups (re-)involved in agriculture on a higher level than cheap day-labor[20]. More data on the number of these groups are needed including analysis of the reasons for their poverty (gender!). Also their vulnerability to climate change should be analyzed, e.g. the exposure of their houses and huts to landslides. The review on the UN-decade of mountain partnerships in CSD 2012/13 might be regarded as a chance to give inputs and to advocate for agricultural research in this field.
- Intensify research on the ecological footprint of agricultural products, first for the development of targeted strategies to reduce the footprint and second for better advising national bodies on favorable crops and technologies. Currently the ecological footprint is the most rational approach to discuss consumption patterns.
- With view to climate change intensify research on desertification fueled by goats and develop guidelines for projects with goats.
- Increase PGR concerning herbs and medicinal plants in mountainous areas, as theses plants are of high value, but face an extremely high risk of extinction due to global warming. Think about cooperation with Tibetan and Chinese doctors, who are experts on plants and their beneficial use.
- Concentrate agricultural research on developing methods, crops, animals and value chains, which allow villages and farmers to make their income in the area they are now.
- Discuss whether it is favorable for CGIAR as an organization to play a more active role on the multilateral level. The above mentioned suggestions for further or intensified multilateral CGIAR

[20] e.g. land laveling, grafting of fruit trees, bee-keeping, processing of food, afforestation, nurseries, cultivation of herbs and pharmaceutical plants, advocacy for land allocation (fruit trees or horticulture), pasture-management, isolation of houses by local materials, improvement of heating facilities with local materials.

activities to increase global focus on food security, climate change and agricultural research require intensive discussion. - The focus of multilateral activities in future will probably be on climate change and on peace keeping. With view to decreasing funds for agricultural research it might be favorable to point out, that agriculture and agricultural research are important stakeholders in both subjects.

- Discuss whether it is favorable to get more involved in the newly established “Adaptation Fund”, which is operated by GEF.
- Intensify research cooperation with research institutes for nature protection on prospected changes of biodiversity of ecosystems/de-coupling the synchrony of inter-dependent species in ecosystems in the course of global warming and the impact of these changes on agriculture.
- Invest already now in research, how to adjust agricultural research and policy for the 30ies, 40ies and 50ies. Abrupt and heavy disruptions will probably be prevalent in all areas: climate, natural disasters, water, biodiversity and clockwork of ecosystems. Specifically when the tipping points of climate change will be reached, quick response on changes and high flexibility will be necessary to avoid high increase of food insecurity and conflicts. At present agricultural research works within the philosophy of “management”, but after reaching the tipping points “management of natural resources” might become a term of the past and “quick response” will be the day-to-day-practice.

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7. Annexes

Annex 1: Occurrence of progenitors of cultivated species within the CAC/Near East Center of Crop Diversity (Zhukovsky 1985): focus on Armenia, Azerbaijan, Georgia and Turkmenistan

Species	Species	Species	Species
Allium porrum	*Corylus colchica*	*Linum usitatissimum*	*Triticum araraticum*
Amygdalus communis	*Corylus colurna*	*Malus orientalis*	*Triticum boeoticum*
Amygdalus fenzliana	*Corylus iberica*	*Malus turkmenorum*	*Triticum dicoccum*
Amygdalus georgica	*Corylus imeretica*	*Mandragora turcomanica*	*Triticum ispahanicum*
Amygdalus scoparia	*Corylus maxima*	*Medicago cancellata*	*Triticum macha*
Amygdalus turcomanica	*Corylus pontica*	*Medicago daghestanica*	*Triticum militinae*
Amygdalus urartu	*Cucumis melo*	*Medicago dzhavachetica*	*Triticum monococcum*
Armeniace vulgaris	*Cucumis sativum*	*Medicago hemicla*	*Triticum paleo-colchicum*
Avena byzantina	*Cydonia oblonga*	*Medicago romanica*	*Triticum persicum*
Avena sativa	*Daucus carota*	*Mespilus germanica*	*Triticum spelta*
Beta corolliflora	*Ficus carica*	*Onobrychis altissima*	*Triticum timopheevi*
Beta lomatogona	*Genus Aegilops*	*Onobrychis transcaucasica*	*Triticum urartu*
Beta macrorhiza	*Genus Morus*	*Pisum elatius*	*Triticum vavilovii*
Beta vulgaris	*Genus Pyrus (25 spp.)*	*Prunus cerasifera*	*Triticum zhukovskyi*
Brassica oleracea	*Genus Rosa*	*Prunus domestica*	*Vavilovia formosa*
Castanea sativa	*Hordeum distichum*	*Prunus spinosa*	*Vicia ervilia*
Cerasus avium	*Hordeum spontaneum*	*Punica granatum*	*Vicia narbonensis*
Cerasus vulgaris	*Hordeum vulgare*	*Secale ancestrale*	*Vicia pannonica*
Cicer arietinum	*Laurocerasus officinalis*	*Secale cereale*	*Vicia sativa*
Cornus mas	*Lens culinaris*	*Secale montanum*	*Vitis labrusca*
Corylus avellana	*Lens nigricans*	*Trifolium apertum*	*Vitis sylvestris*
Corylus cervorum	*Lens orientalis*	*Triticum aestivum*	*Vitis vinifera*

Annex 2: Occurrence of progenitors of cultivated species within the CAC/Central Asian Center of Crop Diversity (Zhukovsky 1985): focus on Kazakhstan, Kyrgyzstan, Tajikistan and Uzbekistan

Species	Species	Species
Allium cepa	*Crataegus altaica*	*Medicago sativa*
Allium sativum	*Crataegus hissarica*	*Persica vulgaris*
Amygdalus bucharica	*Crataegus pontica*	*Phaseolus aureus*
Amygdalus communis	*Crataegus songarica*	*Pistacia vera*
Amygdalus petunnikovii	*Crataegus turkestanica*	*Pisum sativum*
Amygdalus spinosissima	*Cucumis melo*	*Prunus cerasifera*
Amygdalus ulmifolia	*Daucus carota*	*Prunus ferganica*
Amygdalus vavilovii	*Elaeagnus angustifolia*	*Pyrus boissieriana*
Armeniaca vulgaris	*Elaeagnus orientalis*	*Pyrus bucharica*
Brassica campestris	*Elaeagnus songorica*	*Pyrus cayon*

Carthamus tinctorius	*Fragaria bucharica*	*Pyrus korshynskyi*
Cearasus erythrocarpa	*Gossypium herbaceum*	*Pyrus regelii*
Cerasus alaica	*Juglans regia*	*Pyrus sogdiana*
Cerasus amygdaliflora	*Lathyrus sativus*	*Pyrus turcomanica*
Cerasus chodshaatensis	*Lens culinaris*	*Pyrus vavilovii*
Cerasus microcarpa	*Linum usitatissimum*	*Saccharum spontaneum*
Cerasus pseudoprostrata	*Malus hissarica*	*Secale cereale*
Cerasus tadzhikistanica	*Malus juzepczukii*	*Spinacea oleracea*
Cerasus tianschanica	*Malus kirghisorum*	*Triticum aestivum*
Cerasus turcomanica	*Malus linchevskii*	*Vicia faba*
Cerrasus verrucosa	*Malus niedzwetzkyana*	*Vitis vinifera*
Cicer arietinum	*Malus sieversii*	

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