The Impact of Climate Change on Agricultural Land Resource and Land Management

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Abstract

An attempt was made to structure the agricultural land resource in relation to climate change from view point of i) a "passive" victim - or profiteer, ii) an "active" promoter and iii) from possible measures in land management or awareness rising.

A framework of dependencies in climate change and land resource management is employed to show possibilities of fine tuning adaptation and jointly solve other problems or to allow tradeoffs with other topics of concern.

Introduction

In light of scientific evidence of extreme and unpredictable climate change agricultural land resources all over the world and in Asia Pacific in particular will face the challenge of climate adaptation. As defined by the Intergovernmental Panel on Climate Change, adaptation includes a set of actions to moderate harm or exploits beneficial opportunities in response to climate change. We consider the Asia-Pacific Region, the largest global region with a variety of countries, regions and landscapes including an enormous range of agricultural land resources and land management practices. I want to present an outline on how we could consider this topic from a practical point of view. There are three separate areas closely interrelated. Climate change is having an impact on the physical system, in our case the agricultural land resource. The agricultural land resource provides the basis of food production. It might come out of balance by adverse climate change impacts. This in turn gives some pressure on land management. Land management has again an impact on climate change.

We can consider all three areas in relation to each other:

1. Impact of climate change to agricultural land resource: How, and to which extent, had the climatic phenomena of the past (gradual climate change, variations of mean values and climate extremes) an effect on the agricultural land resource. Today, we find information about the dynamics of climate parameters (IPCC 2007). Here we may also consider that intensification in agricultural production had also an impact on the growing season and the climatic suitability of periods used for agricultural production. Rice production cycles could be reduced from 160 to 120 days. Instead of two harvests, three harvests become possible. However, if we use the full potential of today we have no chance to avoid critical climatic periods like typhoons for the production cycle and impacts of extreme events are automatically more likely in such a case.

2. The impact of land management to climate change: A line with economic growth, we find increased possibilities for agricultural production and increased levels in resource consumption. Inputs to agricultural production seriously increased over the past decades. They are responsible for agriculture related greenhouse gases. The secondary emissions of greenhouse gases in agriculture which are related to the inputs to agriculture are not targeted by this relation, but important (Breiling et al. 2005). New concepts like the virtual water (Oki and Kanae 2004) can help to understand the nature of resource consumption and can explain that it is often difficult to judge climate change just based on greenhouse gases.
3. The interaction of the agricultural land resource with land management: is influenced by a number of factors. There are several ways and methods to avoid excess greenhouse gas emissions by various methods of CO_2 fixation. Avoided deforestation, the protection and enhancement of soil organic matter (SOM), precision agriculture, minimum tillage methods are mentioned as good practice here. Depending on the magnitude of the perceived problem we may find response strategies to climate change. They are commonly supported by national and international policies to abate climate change. The strategies widely depend on structural factors, the country´s, region´s or farm's capacity (i.e. size, past performance, part of larger agricultural alliance) (Adger et al 2009).

Figure 1: Two Asian agricultural land resources and their connection to climate change

Explanation: Two agricultural land resources in Sri Lanka and in China. They are different in nature but are increasingly more exposed to climate change impacts. Climate adaptation to cope these impacts are upcoming challenges: 1 describes the impact climate change on agricultural land resource, agriculture is seen as "passive"; 2 explains the impact of land management on climate change, agriculture is "active"; 3 describes benign land management to improve the resilience of agricultural land to climate change

Climate Change & Agricultural Land Resource (1)

Kinds of climate change impacts

Climate change involves shifts in means and in variances, and affecting the probabilities of extreme events. A main reference points are climate related "event-driven extremes", examples of which are well known (Easterling et al 2000). Per definition, extreme events are *rare* events and place specific; thus any prognosis impairs a large error. But following the baseline of warming, new fundamental extremes (Travis 2008) are likely to be observed in the future and the occurrence of absolute thresholds related to the identified crop based extremes will be registered more frequently in a warming situation. "Long-term climate change" (Hasselmann et al 2003) has a time dimension of several decades or centuries. The biophysical characteristic of the climate system that stores greenhouse gases for long periods and has a delayed effect on the socioeconomic system is reflected in it. A major portion of research has concentrated on this phenomenon of "conventional gradual climate change". Travis (2010, p. 3) found out that most studies have essentially assumed that the climate changes "gradually" (albeit at a historically fast rate under the most extreme projections) "smoothly" (Arnell et al 2005) and longterm (Fischer et al. 2005). One can differentiate between medium and short-term periodicity/variability in a sample (Greenland/Kittel 2002). Responses to some recent extreme climate events reveal higher levels of vulnerability in both developing and developed countries than was assessed previously (IPCC 2007). Beniston (2004) differentiates in line with others (Garnaut 2008) three key principles of defining extreme events. First, how *rare* they are, second, how *intense* they are, and third, which impacts/losses they could have. This criterion is difficult, because in many instances, many damaging natural hazards can be triggered in the absence of an intense or rare climatic event (see Fig. 2 and Fig.3). Wilby et al. (2009, p. 1194) stress the need of near term climate scenario tools. Based on historical records in another field (water sensitivity), Morehouse et al (2002) analyzed future severe climate extremes and developed this perspective by adopting *experience based scenarios* that could *reasonably* occur in a limited time frame usable for decision making. We propose to investigate at least a period of 30 years (f. e. 1980 -2010) and to see which influences can be expected in the future based on this "historic" development. Climate risks and their related damage will become evident.

Extreme events and their variability are more important than averages in temperature due to a simple observation. As the primary mainly adverse impacts on society results from extreme events society tends to notice the extremes, variability of weather more than the losses of a potential change in the long future (Katz/Brown 1992). But we know that long term changes may result in numerous consequences in different sectors and may influence extreme wheather events (Beniston/Stephenson 2004).

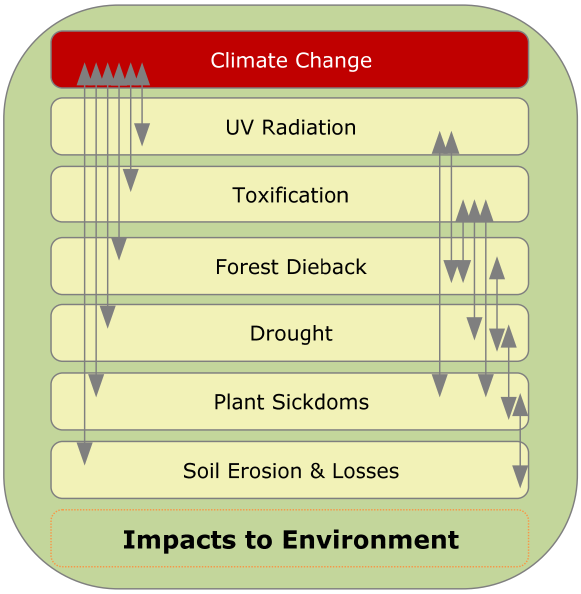
Matching climate and production season of agricultural crop

For the success in agricultural production, the matching of the particular climate period with the crop growing period is decisive. Just taking rice production as an example, we can find varieties for almost any climate and region (Harata 1996). The mean temperature difference between the extremes can be as much as 20°C. Against this, a temperature rise of 5°C does not necessarily mean a catastrophe unless I am already today in a very hot region and a more heat resistant variety cannot be found. The variation of monthly means might be the larger problem as the number of hot month with negative effects can increase considerably. An extreme event that hits a field outside the production period does not cause damage to the crop but eventually to the infrastructure of agricultural production. A smaller climate event that coincides with a critical plant growth period can cause more damage than the larger climate event.

<u>Analysis of the weight of climate change impact on the agricultural land resource in relation to other phenomena</u>

So a single climate consideration is not always useful to assess the likely magnitude of climate events. The climate event is also embedded in a chain of other problem fields which should be considered as well. In figure 2 we depict some of the known environmental stress factors. They increase, decrease or are neutral to the climate change impact.

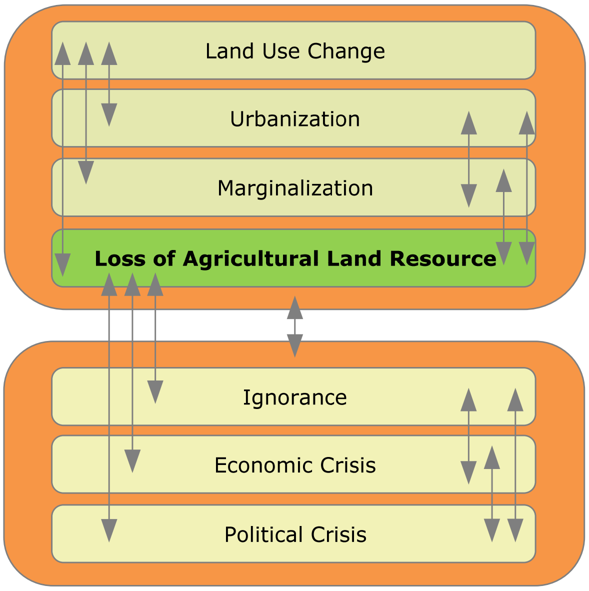
Figure 2: Environmental stress factors and interactions generating vulnerability of agricultural land



Explanation: Climate change is one important environmental stress factor. There is no single cause – impact relation. The combination of several stress factors leads to an impact and it is very hard to proof the weight of each of the involved factors.

The environmental stress factors are different in scale and magnitude of their impact. Soil erosion is a local phenomenon, plant sickness, drought, forest dieback are increasingly more regional. Their impacts vary from place to place and usually an assessment at the spot is necessary to clarify the likely weight of climate change in relation to other environmental stresses. The relation between climate phenomena and socio-economic impact, policy related response measures in a broad sense (past and future oriented), and the corporate stakeholders' risk perceptions of climate phenomena are equally important. Often scholars differ between *end-point* and *starting-point approaches* in research into climatic effects. The first approach emphasizes biophysical environmental stress factors as the main problem to be solved and, what is more important, a vulnerability of a social unit is "the end point of a sequence of analyses beginning with projections of future emission trends, moving on to the development of climate scenarios, thence to biophysical impact studies and the identification of adaptive options". Without the same methodological design, the starting-point approach considers vulnerability as a characteristic that is generated by multiple factors and processes within the addressed social system (Adger/Kelly 2000, p. 326).

Figure 3: Socio-economic political stress factors



Explanation: Beside climate change and other environmental factors there are human development or political stress factors contributing to the loss of agricultural land.

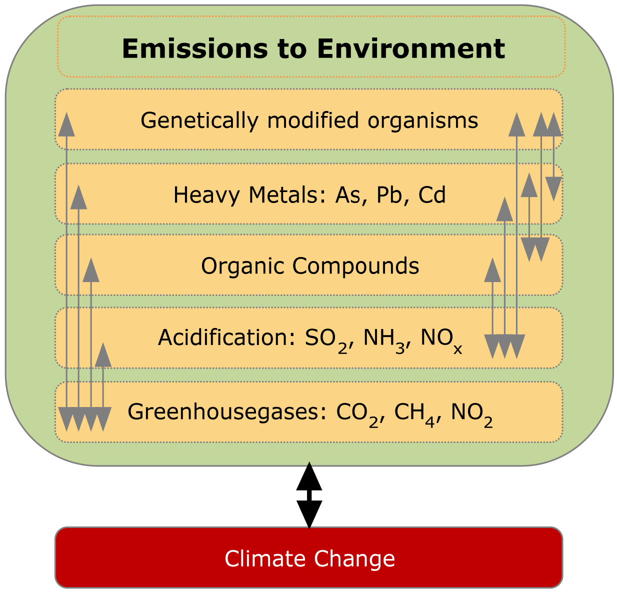
Agricultural Land Management and Climate Change (2)

In industrial countries, an enormous wealth was created during the last decades and never before so many people could live in favorable conditions. Other countries are following and resource consumption will further increase in the Asia-Pacific Region.

<u>Agriculture and greenhouse gases</u>

However, this wealth is based on increased levels of greenhouse gas production. Again, it is not too easy to relate emissions from greenhouse gases directly to warming. Many other pollutants are emitted to the environment as well and they alter or diminish the effects of warming. Figure 4 shows that also in the field of emissions to the atmosphere we have a complex interrelation.

Figure 4: Atmospheric emissions having different effects to climate parameters



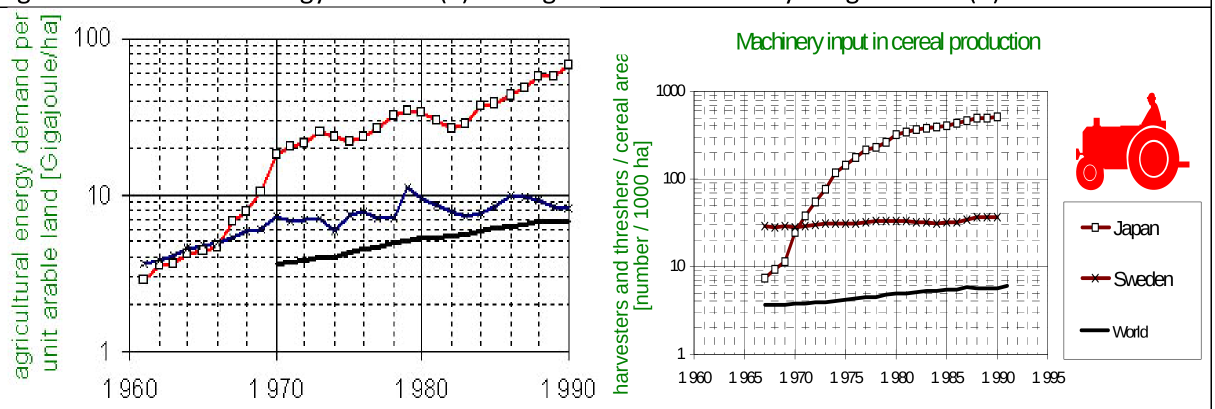
Explanation: Greenhouse gases should not be seen in isolation. Even other gases can have an impact on climate parameters, f.e. acidification gases cool the environment and the co-existence can result in an assumingly stable situation.

There is now increased resource consumption and more pollution into the environment. The amount of greenhouse gases increased rapidly.

<u>Increased resource consumption and effects</u>

In Figure 5 we depict the energy consumption for Japan, Sweden and the world average. In Japan the increase during 1960 and 1990 was most distinct from 2 GJ/ha to 70 GJ/ha. In the same period we find a dramatic increase in tractors and harvesters. Starting with 7 machines per 1000 ha in 1967 we end up with 700 machines for the same area in 1990.

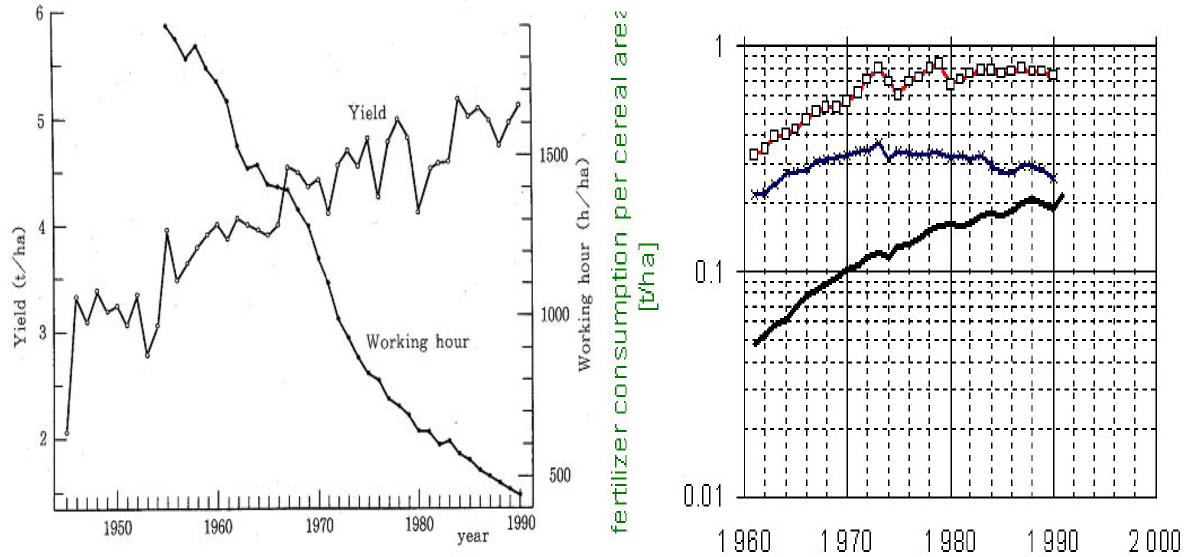
Figure 5: Increase of energy demand (a) and agricultural machinery in agriculture (b)



Source: G. Ahamer, 2001, and Ahamer Global Change Data Base, 1995)

The yields in agriculture went up. The working hours went down and the work load got less and less. Figure 6 shows the trend of Japan during 1950 to 1990, a situation which we find in many other Asian countries just today. Less working hours and higher yield on the same agricultural land resource means a considerable metabolism of inputs. The corresponding value of fertilizer increase in Japan during 1960 to 1990 was from 300kg to 800kg. Japan was and still is far over average, the average global input at that time was rising from 40 kg to 220 kg.

Figure 6: a) Relation of Yield and Working Hours in Japan 1950 to 1990 and b) fertilizer use in Japan, Sweden and the world from 1960 to 1990



Source: 6a) Source: Karube et al. 1995 6b) Source: G. Ahamer, 2001

Consequently, the number of wanted growth is also accompanied by a corresponding emission of greenhouse gases.

<u>Life cycle assessment to test agricultural performance</u>

Agriculture contributes considerably to this development. In a life cycle analysis for Japanese regions, it was found out that not only the quantity of yield, but also the size of farms, the degree of mechanization, the amount of fertilizer and pesticide inputs contribute significantly to greenhouse gas emissions (Breiling et al. 2005). It turned out that small farms with a size of less than 1 ha, but with a sophisticated park of machinery, contributed the most greenhouse gas emissions in relation to the produced quantity of rice. More energy goes into the production than what is harvested as food.

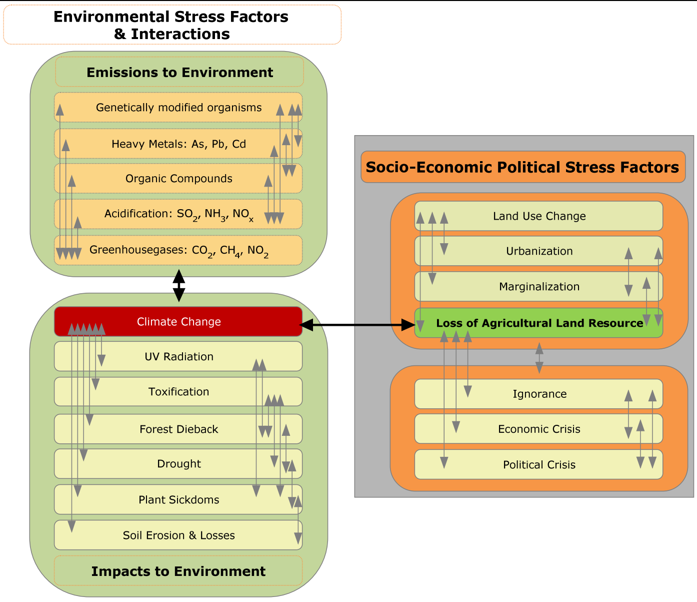
Agricultural Land Resource and Land Management (3)

Here we present some solutions, benign as climate protection measures, suitable to fix CO2 and to increase the resilience to adverse climate change impacts. Most of the measures could be benign for the agricultural land even in absence of climate change. Performing such an action can be beneficial from various standpoints. In figure 7 we employ the combination of figures 2 to 4 to show the combined interactions. Knowing the interdependencies will help to understand in what way the measures are also beneficial for climate change adaptation. There are many small measures to increase the resilience against climate change impacts and we would like to present a few of them, just to show how many possibilities do exist to adapt to further and accelerated climate change.

<u>Improving the soil quality and soil organic matter</u>

In Europe, namely in the Danube river basin, there started the SONDAR initiative (www.sondar.eu) that creates awareness to soil issues. On the one side soil is overbuilt in the more urban areas and on the other side soil is lost by soil erosion or soil marginalization. Looking at figure 7 we see there are a lot of dependencies to climate change and to the agricultural land resource if we only consider soil issues. Therefore the SONDAR team cooperates with climate adaptation groups as there exist common goals (www.klimabuendnis.at).

Figure 7: No regret measures to counter climate change impacts



Explanation: The efficiency of measures can be tested in this conceptual model of environmental stress factors, impacts to environment and socio-economic political stress factors. While it is not possible to quantify the effect of a single measure, we can assure that the direction of impact is wanted or unwanted to climate change adaptation.

The enrichment of soil with organic matter is commercially done in Austria (topagrar 2009, www.grand.at) with the help of earthworms. The animals are bred in particular conditions developed according to a scheme and now even exported to India, where farmers produce earthworms and humus according to an adjusted plan suitable for the local conditions. The earthworm humus is richer in the content of NPK than any other soil or compost and can substitute the artificial fertilizer otherwise used. The higher humus contents improve the capacity to fix CO2 and it avoids the application of artificial fertilizer and the related greenhouse gases. This project was awarded by UNESCO as a decade project for sustainability.

Figure 8: Soil improvement by earthworms – also a source of humus as commercial product

Explanation: Earthworms efficiently enrich the soil with humus and make minerals available for plant growth. An Austrian farmer, who wanted to improve his 100ha of agricultural land, sells now access earthworm humus to gardening facilities and elaborated a license scheme for colleagues, which he sells now worldwide. Thereby he co-generates benefits in climate change adaptation as the resilience of the agricultural land resource increases.
Source of picture: http://www.chilloutzone.net/bild/regenwuermer.html and www.grand.at

Soil erosion is another source of decline for the agricultural land resource. Here it is important to have sufficient trees and shrubs to fix the soil even in the case of extreme precipitation events. A particular program is REDD which stands for reduced emissions from deforestation and degradation launched by the World Agroforestry Centre (2007) in Nairobi. The combination with an increase in organic matters will further increase the resilience of the concerned agricultural land resource.

Creating adequate awareness to protect the agricultural land resource

A rather new problem for many countries in the Asia Pacific is that the rural population is rapidly declining and agriculture is not considered as a very attractive income. Thereby the agricultural resource is marginalized and the lack of concern towards agricultural land can be the source of severe soil degradation. Just by giving appropriate value to the land resource can help to avoid a sudden retreat from rural areas and a shift to even larger problems in urban zones. Programs like REDD of the World Agro-forestry Centre help here and could be further developed. A very successful program, the first of its kind in Europe could help to change the perception of the value of the agricultural land resource. With the help of artists, a competition “colors of the earth” was created (www.soilart.eu). Various villages contributed with a color produced from their particular soil. All together several colors of “the earth” were assembled to a color box.

Children and young stakeholders in focus

Over 30,000 children participated in the competition. Many of the children even learned to produce colors from the earth. Thereby they learned a lot of things on land management and agriculture, a knowledge they would not obtain otherwise: soil is a water storage and filter, which increases with the organic content; beside the earthworm there are many animals living in the earth; good soil conditions help to increase the plant and vegetation cover and help to improve the local climate conditions and to cope with the consequences of extreme weather events;

Figure 9: Awareness rising for young stakeholders

Human concern, in particular of the young generation is important to safeguard the agricultural land and soil as its most important resource. Painting competitions is a simple way to learn about land management, climate and interactions in environment. Source: www.soilart.eu (a) and own picture (b).

Conclusion

In light of scientific evidence of extreme and unpredictable climate change agricultural land resources all over the world and in Asia Pacific in particular will face the challenge of climate adaptation. As defined by the Intergovernmental Panel on Climate Change, adaptation includes a set of actions to moderate harm or exploits beneficial opportunities in response to climate change. An attempt was made to structure the agricultural land resource in relation to climate change from view

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