

Local Adaptation to Global Environmental Change in a Globalized World: Insights from northern Ghana

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1. Introduction

Climate change and economic globalization exert an increasingly high degree of pressure on the agricultural livelihoods of small-scale farmers in West Africa. Global climate change leads to declining yields and the increasing unreliability of local agricultural production systems in an area where the economies of most countries still largely depend on crop growing (Boko et al. 2007: 452ff, Collier 2008: 338). At the same time, economic globalization (in this context, an increase in international trade and the falling of political barriers towards economic exchange) limits small-scale farmers' adaptive capacity towards climate change. Agricultural intensification and the production of cash crops for the market – a pattern of adaptation commonly found throughout the region – is met with competition from extremely cheap agricultural products from Europe, Asia and America, the production of which is often highly subsidized. West African peasants thus become losers both of climate change as well as of economic globalization.

A number of authors (Eakin 2005; O'Brien et al. 2004; O'Brien & Leichenko 2000) have described this kind of 'double exposure' that affects small-scale farmers and agricultural wage laborers in countries such as Mexico and India. They have pointed out that both processes, economic globalization and global climatic and environmental change create winners and losers and that some people are subjected to the negative consequences of both developments. O'Brien and Leichenko (2008: 4-5) argue that the speed, scale and extent of environmental as well as economic, social, political and cultural process of change have been greatly accelerating in the last decades and that different processes of change interact and influence each other in multiple ways. Yet, while this connectivity seems to be obvious, processes of global environmental change and globalization are often framed in different discourses and discussed independently of each other, both by scientists and policy makers. This is disconcerting because pathways of double exposure "often lead to growing inequalities, increasing vulnerabilities, and accelerating rates of change" (Robin Leichenko and O'Brien, 2008: 5), problems that can only be addressed if the dynamics sparked by the interaction between different processes of change are recognized, analyzed and understood. At the same time, because of the failure to analyze and understand the pathways of double exposure, opportunities and synergies that are created by the interaction between global environmental change and globalization are missed.

During the research on local adaptations to (global) environmental change in Northern Ghana the importance of analyzing pathways of double exposure became increasingly apparent as local peasants seemed to become losers both in the realm of global environmental change as well as in the realm of economic globalization. In the following the example of farmer-driven expansion of shallow groundwater irrigation (SGI) in the Upper East Region of Northern Ghana will be discussed in order to show how the double exposure to climate change and economic globalization affects West African peasants.

The Upper East Region is the second poorest region of Ghana. The population is largely dependent on rain-fed agriculture, in which 70% of the population is engaged (GSS, 2002b). Typical products are millet, sorghum, groundnuts, pulses and rice and a variety of local vegetables. In an unpredictable environment earmarked by a long dry season, frequent dry spells and droughts, rain-fed agriculture is a risky business and even in good years agricultural production does not fully cover the food demand of many households. As in other parts of Africa (Ellis 1998, Ollivier de Sardan 1988), local peasants have diversified their livelihood activities as an adaptive strategy to mitigate risks and to cope with disasters. Rain-fed agriculture is combined with animal rearing, hunting and gathering, trade and (migratory) wage labor and agricultural production is intensified, mainly through the adoption of irrigation practices and the adoption of new crop varieties (Laube, 2007: 151 ff; Tonah, 1993: 139 ff).

Climatic changes have always had, and continue to have, a large impact on local agricultural production: from the 1960s to the 1990s West Africa encountered a particularly dry period, with terrible droughts in the Sahel and the semi-arid Guinea-Savannah, particularly in the late 1970s and early 1980s, but rainfall averages have since recovered (Hulme 2001). Regional climate models predict a moderate increase in precipitation throughout the region, but with considerable local variation (Jung et al. 2007, Paeth 2004). Furthermore, the onset of the rainy season has shifted from April to May and dry spells during the rainy season have increased (Laux et al. 2008). According to regional climate model projections developed from the results of global climate change models, this trend will become more pronounced, and climatic patterns more unpredictable and erratic, than they were previously. This increases the probability of the occurrence of extreme events such as floods and droughts, and thus the danger of more harvest and food insecurity (van de Giesen et al. 2010).

Apart from climatic changes, large population growth has occurred over the last century. The population almost doubled between 1960 and 2000 and the population density has reached 104 persons/km², well above the average national level of 79 persons/km² (GSS, 1989b, 2002a). This has led to increasing pressure on natural resources such as soils, pastures and forests. Degrading resources have led to decreases in the output of the traditional agro-pastoral production system consisting of rain-fed agriculture and livestock husbandry.

As in other parts of Africa (Ellis 1998, Ollivier de Sardan 1988), local peasants living in an unpredictable environment often diversify their livelihood activities as an adaptive strategy to mitigate risks and to cope with disasters. Diversification techniques within agriculture – planting different crops, differently located farm types, intercropping and animal husbandry, hunting and gathering, trade, migratory wage labor and a wide array of social institutions that enhance redistribution, reciprocity and solidarity in times of need – have helped local farmsteads to adapt to a difficult environment (Laube 2007: 151 ff, Tonah 1993: 139 ff).

Faced with increasing pressure on their agricultural livelihoods, local farmers have adopted further coping and adaptation strategies. Permanent and seasonal migrations are important coping strategies, as they help to reduce pressure on available resources and create additional income for consumption or investment (Schraven, 2010). In order to adapt to environmental changes, in many parts of the UER agricultural production has been intensified, mainly through the adoption of irrigation practices and the adoption of new crop varieties (Tonah 1993: 140). The expansion of irrigated agriculture comes partly as the result of governmental efforts to enhance local agricultural production, but is nowadays very often a farmer-driven development. Thousands of farmers have started the production of vegetables such as tomatoes, onions and peppers using water from perennial rivers and shallow groundwater aquifers. This development has not been instigated by the government or other development

agencies; it is the result of the local adoption and dissemination of new crops, techniques and knowledge that has proved to be potentially profitable. Smallholders try to profit from new market chances, as they attempt to adapt to mounting economic and environmental pressure.

Vegetables grown by small-scale farmers in the UER are produced mainly for the national market, and mostly sold to traders who sell them in the urban centers of southern Ghana. Where practiced, irrigated agriculture proves to be able to enhance household incomes considerably and to decrease rural-urban migration, and farmers see it as an important means for the adaptation to (global) environmental change. However, despite these benefits, irrigated vegetable production remains a risky business. Apart from crop diseases and occasional water shortages, the failure of vegetable markets limits the benefits obtainable from irrigated agriculture. Market failure is most pronounced with regard to tomato production, especially due to the perishable nature of this produce, but it also affects the sale of other vegetables such as peppers and onions. The marketing of irrigated vegetables therefore suffers from a number of flaws. In Ghana, national vegetable market channels are monopolized by women trader organizations that exert a large degree of control over commodity prices, often to the farmers' disadvantage. Further, local farmers face a high degree of competition from other countries within the sub-region (Burkina Faso for tomatoes, Mali and Niger for onions).

However, imperfect national markets and regional competition could be dealt with, if farm produce could be processed locally. However, attempts to establish functioning food processing industries are bound to fail. They are met with stiff competition from European, American and Asian countries, where the production and processing of vegetables are highly intensified, benefit from economies of scale, and are often also subsidized. Therefore, large quantities of cheap vegetables and vegetable products (such as tomato paste) are imported into Ghana. Bound by WTO regulations and due to loan conditions, the Ghanaian government is unable to create a level playing field for local farmers through the imposition of increased import taxes. Artificially low world market prices thus negatively affect local prices, marketing chances and the potential for the establishment of a domestic processing industry. Patterns of regional and global economic exchange, therefore, largely limit local, small-scale farmers' adaptive capacities with regard to environmental change. This can clearly be seen in the study of patterns of local adaptation to environmental and climate change in the Anayere and Atankwidi catchments of the UER in Northern Ghana.

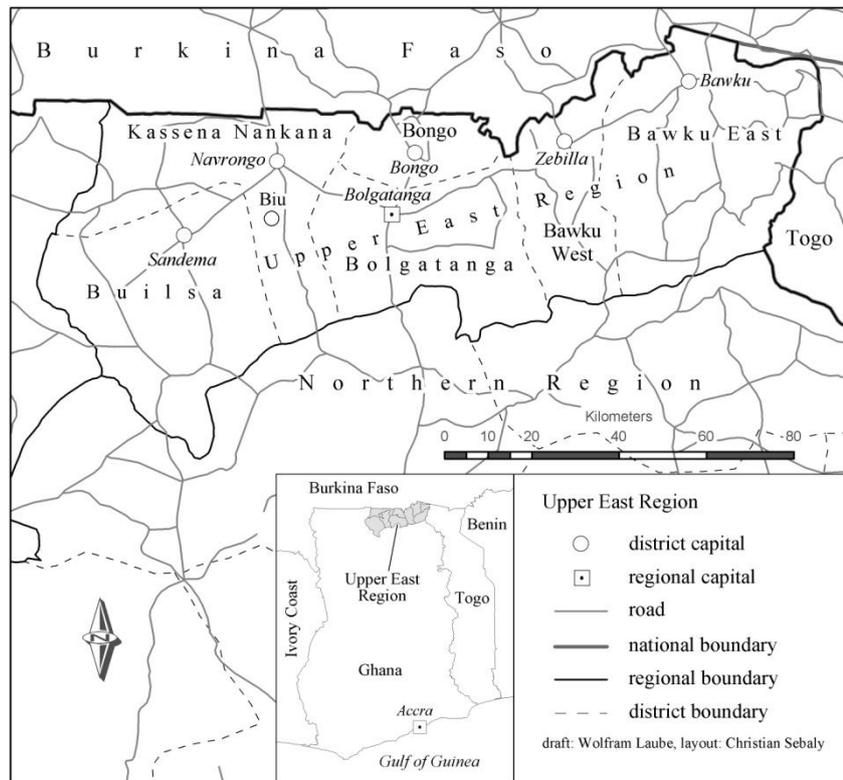
2. Research Area and Methodology

The research that underlies this paper has been conducted in the Kassena Nankana District and the neighboring parts of Bongo and Bolgatanga Districts of the UER in Northern Ghana. The population consists mainly of Kassena, Nankana and Builsa ethnic groups. While these ethnic groups speak different languages, they inhabit overlapping territories, which also extend beyond the border into neighboring Burkina Faso, and there is a large degree of intermarriage. Kassena, Nankana and Builsa largely share the same forms of social and political organization and culture. Kinship is organized in patrilineal lineages, clans and sections and most people live in large compounds - on land owned by the lineage - that frequently host large extended families. Chieftaincy is the central local political institutions, at least since the British established a system of indirect rule by local chiefs during the colonial period (Der, 2001; Laube, 2007: 51; Lentz, 1998). Territorial control lies in the hands of the lineage that claims to have first settled within an area: they become the earth priests¹ of a certain territory. Through their

¹ Earthpriests are called '*tinyono*' in Buli, '*rigatu*' in Kasem and '*tindana*' in Nankam.

rituals they ensure the spiritual and physical wellbeing of land and people and, especially in rural areas, they control the allocation of land.

Fig. 1 The Upper East Region, northern Ghana



Northern Ghana has been, since colonial times (1904-1957), the poorest part of the country. The area is characterized by difficult climatic conditions, relatively high population density and patterns of underdevelopment, which are the result of discriminatory colonial and post-colonial policies (Ladouceur, 1979). The Upper East Region is the second poorest region of the country, and levels of poverty have increased throughout the 1990s, despite an impressive reduction of poverty in the country overall. Officially, 88% of the rural population fell below the official poverty line in 2000 (GSS, 2000: 13). However, there is indication of a slight reduction in poverty between 1998 and 2006 (Coulombe and Wodon, 2007: 10; GSS, 2008). The region has experienced significant population growth as the population almost doubled between 1960 and 2000 and the population density has reached 104 persons/km², well above the average national level of 79 persons/km² (GSS, 1989b, 2002a). About 70% of the population is dependent on rain-fed agriculture as the main contributor to their livelihoods (GSS, 2002b). They grow crops such as millet, sorghum, groundnuts, pulses and rice and a variety of local vegetables.

In an unpredictable environment earmarked by a long dry season, dry spells and droughts, rain-fed agriculture is a risky business and even in good years agricultural production does not fully cover the food demand of many households. As in other parts of Africa (Ellis 1998, Ollivier de Sardan 1988), local peasants have diversified their livelihood activities as an adaptive strategy to mitigate risks and to cope with disasters. In the rural research area, basic infrastructure such as roads, schools, clinics and increasingly access to the power grid is provided by the government. The expansion of irrigated agriculture is partly the result of governmental efforts to enhance local agricultural production, but also a farmer-driven.

The expansion of irrigated agriculture and the economic, social and political dynamics that it entails became the interest of my research. Sponsored by GLOWA Volta Project (GVP) I conducted 12 month of field research on changing natural resource regimes in the Tono Irrigation Project in the Kassena Nankana District from 2001-2003. In the following years, the GVP provided me with regular opportunities to revisit the research area. My interested shifted to farmer-driven groundwater irrigation, which was largely expanding during that time. In 2005, together with a multidisciplinary team we started an intensive study of groundwater irrigation development in the Anayere and Atankwidi catchments. Anthropological field research, quantitative socio-economic surveys, farm observations and a hydrological monitoring of surface and groundwater resources were undertaken. The GVP research was complemented by the Shallow Groundwater Irrigation Project (CP 65) of the Challenge Program for Water and Food, which enabled a continuation of the research. Anthropological research included in-depth interviews and group interviews with local farmers, farmer leaders, traders, local chiefs and earth priests and representatives of the Ministry of Food and Agriculture. This served as the background for further qualitative and quantitative research by a number of PhD, MA and BA students (Amegashitsi, 2009; Awo, 2007, 2010; Deiting, 2009; Lehmann, 2009; Schraven, 2010) and for a survey conducted in 2006, 2007 and 2008. Secondary data provides further background for the paper.

3. Climatic and environmental changes

The study area is situated in the West-African semi-arid Guinea Savannah belt where the standard 'climatic year' can be divided into two seasons: the dry season from November to April/ May, with only marginal rainfall, and the wet season from May to October. The amounts of rainfall in Northern Ghana vary according to the location from 1,000 up to 1,300 mm per annum. In average years, about 60 % of precipitation can be expected from July until September. The mean annual temperature is averagely 28.6 °C, but in March and April, usually the hottest months, the average temperature is more than 32 °C (Kranjac-Berisavljevic et al. 1999: 5 ff.). High temperatures are accompanied by high potential evapotranspiration (up to 2000 mm) that results in severe seasonal water shortages.

In Interviews farmers say that within the last twenty years they experienced a shift in the onset of the rainy season (May or June instead of April) and that traditional signs for the onset of the rainy season (certain behaviors of birds and ants, changing wind patterns, the coming of new leaves, etc.) have become unreliable (see Dietz et al. 2004: 159 for similar findings on Northern Ghana, or Roncoli et al. 2002 for similar findings in neighboring Burkina Faso). Local observations are confirmed by regional climate models projecting that the shift in the onset of the rainy season will continue in the coming decades. According to these projections, between 2030 and 2039 the rainy season may even start later than June in Northern Ghana (Jung and Kunstmann 2007).

Rainfall levels in wide parts of West Africa have changed. From 1970 up to the beginning of the 21st century, the decrease of mean annual rainfall levels ranged from about 10% for the wet tropical zone to more than 30% for the Sahelian zone (Niasse 2005: 4). For the whole Volta Basin, the mean precipitation amount decreased by 10% from 1,100 mm per year between 1901 and 1969 to 987 mm per year between 1970 and 2002 (Kranjac-Berisavljevic et al. 1999: 5 ff.). However, since the late 1980s and early 1990s a clear increase in rainfall amounts can be observed (Hulme 2001) and some authors interpret the rainfall pattern of the 1970s and 1980s as major climate deterioration rather than an indicator of a process of long-term climate change (Dietz et al. 2004:154-157). Climate models do not predict any significant changes in overall rainfall amounts for the next decades. However the rainy season will shorten and the rainfall intensity therefore increase (van de Giesen et al. 2010: 1034). Increasing variability of the onset

of rains as well as the growing intensity of rainfall enlarges the probability of extreme events such as dry spells, droughts and floods.

Apart from changes in precipitation, climate models for the Volta Basin predict that average temperatures in the Upper East Region for the decade straddling 2030-2039 will increase further by up to 1.5 C on average as compared to the decade of 1991-2000. This will bring along further increases in evapotranspiration (van de Giesen et al. 2010). However, the drastic increase in population that the region has experienced since the advent of colonial rule (Songsore 1996:55). Also contributes to environmental change. In the last forty years, the local population in the Kassena Nankana District has increased by approximately 70% (GSS, 1989a, 2002a). As a result of the expansion of agricultural land, bushfires and the high demand for firewood, forest cover of the research area is vanishing. In the search for firewood, pasture and arable land, former bush areas are increasingly deforested and turned into bush farms (Blench, 1999). Deforestation, overgrazing and bushfires have degrading effects on the poor soils of the area, especially in bush farms, where soil fertility is not replenished through manuring (Kpongor 2007:37 ff.; Vlek and Braimoh 2005:362 ff.).

However, neither local population growth nor increasing population densities alone contribute to degradation processes in northeast Ghana's physical environment. Population pressure on natural resources could be mitigated if rain-fed agriculture was intensified or alternative economic options were developed. But this has been prohibited by international developments (Songsore, 1996). As part of the conditions for continued donor support, agricultural subsidies, government provision of fertiliser, and rural development programs have been abolished since the structural adjustment programs of the 1980s and attempts to reintroduce fertilizer subsidization in 2008 did not work effectively and were stopped in 2011. As a result, the intensification of rain-fed agriculture, which is one possible adaptation strategy in the case of population growth (Boserup, 1965), is not really an option in the research area, especially since increasing climatic variability renders high investments in rain-fed agriculture extremely risky. Social specialization, economic diversification and technological innovation are all factors which have mitigated population pressure on natural resources elsewhere in Africa (Tiffen et al. 1994), but in the research area population growth rather led to an expansion and permanent use of farmland (Songsore, 1996) with the resulting in considerable environmental degradation.

4. Local Environmental Adaptations

Peasants have developed various ways to adapt to the particular uncertainties of the environment they are living in. Successful strategies include the reliance on risk-mitigating patterns of production (Carter 1997), diversification of agricultural production (subsistence and market production) (Elwert 1983, Ellis 1998), developing alternative sources of livelihood (Bryceson 2002) and social coping strategies in the case of disaster (Scott 1976, Ollivier de Sardan 1988, Adams et al. 2002).

To cope with climatic uncertainty peasants in the research area plant and intercrop different crop types across different growth periods and with diverse moisture requirements. They also cultivate farms in different locations (compound farm, family farm, bush farm) with different soil types to increase the chance that at least some crops will survive under extreme weather conditions (Laube 2007: 151 ff; Tonah 1993: 139 ff). Additionally, they engage in the raising of cattle, goats, sheep, donkeys, pigs and different varieties of fowl. Livestock helps many households to adapt to regular food shortages that regularly occur in the rainy season before harvest and to cope with famines that may occur as the result of droughts or floods, when livestock is sold to purchase foodstuffs (Adams et al. 2002:268, Tonah 1993: 142).

Foraging is also part of many households' livelihood portfolio (Tripp 1999: 252), and directly supplements household food requirements. But prey, fish and fruits are also sold at local markets (Laube 2007). The fruits of the Shea (*Vitellaria paradoxa*) and Kapok tree (*Ceiba pentandra*) are gathered, processed and sold via middlemen in national or even global markets (Chalfin 2003). Petty trade, mostly by women, is an additional source of income in most peasant households, and some men engage in the long-distance trade of animals (Tripp 1992: 254).

Furthermore, social institutions, norms and values that enhance redistribution, reciprocity and solidarity in times of need, e.g. the sharing of land, labor and food, seed lending, the reliance on in-laws and the redistribution of foodstuffs through funerals, have helped local farm households to adapt to the environment and to cope with crises (Laube 2007, Tonah 1993).

As environmental change threatens their agricultural livelihoods, local households have adopted different adaptation strategies. The reduction of planting time that comes along with the shift of the rainy season has affected traditional cultivation patterns. During group discussions farmers said that they have replaced types of millet, guinea corn and groundnuts that have a long growth period with types that mature faster and that the cultivation of groundnuts in less fertile soils, and the production of short-growing varieties of maize (with the application of chemical fertilizer) are increasing (Laube et al. 2007).

A very important coping and adaptation strategy is labor migration to southern parts of Ghana. Labor migration has a long history dating back colonial times and (Lentz, 1998; Nabila, 1987). The relatively low population growth of the Kassena Nankana District between 1948 and 1960 (from 91,051 to 93,397) is attributable to the out-migration of almost 20% of all people born in the district (Kumedzro, 1970) and also accounts for the fact that the population of the Kassena Nankana District remained almost unchanged between 1984 and 2000. Migrants go to southern Ghana in search of work in the mining sector, the plantation economy or in the urban areas. Furthermore, seasonal migration usually takes place during the dry season, when agricultural production comes to a halt and demand for labor in the south is high. However, interviews with peasants showed they are increasingly aware of the risks and disadvantages of migration and that the profitability of migration is decreasing. Difficulties in finding jobs, provisions for employment agents and, low wages, as well as the greatly rising cost of food, accommodation, and transport, have made migration less attractive (Amegashitsi 2009; Schraven 2010). Nevertheless, migration continues to be an essential source of income

for local households, and remains an important coping strategy in crises (see Lay et al. 2009 for similar patterns of migration in neighboring Burkina Faso). In the last couple of years local peasants have therefore sought to find alternative sources of livelihood and have started to develop shallow groundwater irrigation in large numbers.

5. Adapting to Change: Shallow groundwater irrigation

Although SGI-technologies have been known to some peasants in the research area since long SGI-expansion is a rather recent phenomenon. According to local informants, SGI in the research area was introduced by a returning migrant in the 1950s. But irrigation was not in high demand and knowledge rarely spread across village boundaries. In general, irrigation became more widespread when the Ghanaian government in 1957 commissioned the construction of 104 dams fitted with irrigation infrastructure in the Upper East Region. However when the governmental irrigation agency withdrew from the management of the schemes, the infrastructure collapsed and irrigation farming became impossible. Irrigation only resumed when the dams were rehabilitated in the late 1990s under farmer and put farmer management (Gyasi 2005: 30 ff). The construction of two medium-scale irrigation schemes in Tono and Veve, from the late 1960s until 1985, also influenced regional irrigation development. Initially, forceful expropriation of project land, skewed land allocation that favored state farms and commercial farmers as well as oppressive project management led to the withdrawal of most peasants (Konings 1986) and in the early 1990s, when state farms had collapsed and most commercial farmers had lost interest in farming, large tracts of project land lay idle. But from the mid-1990s onward, when the potential benefits of irrigation became visible and markets for products such as rice, soya bean but also tomatoes established demand for irrigable land has increased, and has even led to land conflicts in Tono and Veve (Laube 2007: 97 ff).

However, the governmental promotion of irrigation in small- and medium-scale irrigation schemes only benefited a minority of farmers. Therefore, in the mid-1990s, hundreds of peasants faced with the degradation of natural resources and the decline of rainy season farming, started to develop their own irrigation facilities and established vegetable gardens along the dry riverbeds of the Anayere and Atankwidi rivers. The recent proliferation of irrigation practices can also be seen from the fact that more than 80 % of the irrigation farmers interviewed in 2006 had less than ten years of irrigation experience, while more than 57 % of the farmers had only practiced irrigation for five years.

Farmers use shallow groundwater harvested from wells and dugouts for vegetable gardens. The water is usually fetched with buckets, but some farmers use motor pumps. In 2006, the average size of farms irrigated by bucket was approx. 600 m² (0.06 ha), while the average size of pump farms was about 2000 m² (0.2 ha). According to a remote sensing study the area under SGI in the Atankwidi basin alone has reached more than 387 hectares, representing 1.4 % of the total land area (Barry et al. *forthcoming*). The development of SGI has hinged on a number of preconditions. Tomato production in the UER comes at a time of the year when climatic conditions in the south do not allow for vegetable production. Therefore, medium-scale irrigation schemes have attracted traders, who buy vegetables from the area to cater for the high demand in southern Ghana (Clark 1997: 73ff). Since the early 1990s, the enhancement of road access to Northern Ghana has largely facilitated this trade. Small-scale farmers have responded to the newly developing market chances after seeing how profitable tomato production can be.

The expansion of SGI is also based on local norms and values that facilitate the sharing of knowledge, land and labor. Since agricultural extension services are missing, farmers depend on the knowledge and experience of their colleagues, in order to be able to

adopt irrigation techniques. Practices such as land sharing and labor exchange have helped many poor households to engage in SGI. The impact of SGI on the economic situation and adaptive capacity of peasant households cannot be overestimated. Although farms are relatively small and input levels low, farmers have been able to reap make healthy profits. In 2006 and 2008, respectively, bucket farmers gained an average profit of about 1.5–2 million Cedi (approximately 160 – 200 USD) from their farms. Pump farmers earned about 5.5 – 4.5 million Cedi (approximately 580 – 450 USD). Given the fact that more than 80 % of the population of the UER region has an overall annual income below the official poverty line of 900,000 Cedi (in 2000 roughly 365 USD) (GSS 2000: 13), the additional income gained through SGI is substantive. Farmers therefore see SGI as profitable, and the additional income is spent mainly on additional food purchases, farming inputs, education, health, buildings, means of transport and the purchase of animals. Pump farmers are more likely to make significant investments make more costly investments in buildings, education and farm inputs (see Table 1).

Table 1: Expenditure of dry-season profits per farmer type (%)

	Pump farmers	Bucket farmers
Household expenditures	92.9%	87.1%
Education	35.7%	20.6%
Buildings	45.2%	22.9%
Animals	33.3%	30.6%
Farm inputs	26.2%	15.9%
Health	9.5%	8.8%
Means of transport	4.8%	1.8%

The benefits of SGI become apparent when the wealth of irrigation households and non-irrigation households is compared.² Table 2 shows that the average wealth indicator of irrigation households is almost twice as high as that for non-irrigation households.

Table 2: Wealth indicators of irrigation and non-irrigation households (2007)

Wealth indicator	Non-irrigation households	Mean	24.9
		Std. Deviation	26.6
	Irrigation households	Mean	46.0
		Std. Deviation	48.5

While it seems clear that SGI has helped peasants to adapt to an changing environment, it is difficult to establish a straightforward relationship between the factors of (environmental) change and particular patterns of adaptation (Nielsen & Reenberg 2009: 464, Reid et al. 2000: 340). As shown above, the research area has seen a host of social, political, demographic, infrastructural and environmental changes, which in combination have not only led to environmental degradation and persistent poverty, but also provided chances for new coping and adaptation strategies. Local peasants have responded to opportunities such as labor shortages in southern Ghana, infrastructure development, increasing market integration, the availability of new and

² To measure wealth difference, a wealth indicator was generated. The indicator is based on the quantity of household assets and livestock owned.

advanced crop types and the spread of new techniques and knowledge. However, SGI has clearly led to changes in the local adaptation to environmental and socio-economic change. In past decades, migration has been the major adaptation strategy with regard to population growth, environmental change and regional underdevelopment. In this light it seems significant that 50% of bucket farmers and more than 60 % of pump farmers reported that SGI had changed their migration patterns and they had seasonal migration completely or went for shorter stays. In 2007, in 31% of the irrigation households and 41% of the non-irrigation households had members seasonally migrating. However, the number of migrants from irrigation households was quite high in 2007, because irrigation farmers faced severe tomato marketing problems in the dry season of 2006/2007. Consequently, many farmers lost their capital for SGI. In 2008, marketing was much better and the percentage of irrigation households with seasonal migrants reduced to 16%.

The research area is not the only area in Northern Ghana where these patterns of farmer-driven SGI expansion can be observed, as they also take place in neighboring parts of the Bolgatanga and Kassena Nankana districts, but since this development is not officially promoted accurate figures about the number of farmers and/or hectares are lacking. Specializing in a different crop, onions, small-scale farmers in the Bawku East and Bawku West districts of the Upper East Region have also expanded SGI. Introduced in the 1930s by Mossi immigrants, and initially practiced at irrigation dams (Sinnadurai & Abu 1977: 312, Padmanabhan 2007: 65), SGI onion farming has greatly increased since the late 1990s. Like in the Kassena Nankana District, SGI expansion in Bawku involves both rich and poor farmers, as well as women and the youth (Whitehead 2002: 593). Highly attractive to local farmers and a farmer-driven alternative to costly state-driven irrigation development, SGI in Northern Ghana, nevertheless, faces a number of drawbacks that limit potential adaptive capacity.

6. Limits of adaptation: Market failure and terms of trade

In group discussions and in surveys, farmers mentioned crop marketing, crop diseases and water shortages (ranked in descending order) as the main problems related to SGI. Almost 60 % of the farmers interviewed stated that they had formerly lost crops due to water shortage. The situation was particularly bad in 2006, when after a series of years with rather poor rains the shallow groundwater table had become low, and so many farmers decided to engage in SGI. Some had to dig up to 8 m deep to find water, while others were less lucky and hit an impermeable layer without reaching water. However, after floods in late 2007, the shallow groundwater table increased greatly, and was still very high after the end of the farming season in 2008.

It is clear that SGI can only help to adapt to environmental change as long as sufficient percolation occurs and finite resources are not overexploited. Hydrological research in the Atankwidi basin points to the fact that SGI at the current level is sustainable and could be even slightly expanded (Barry et al. *forthcoming*). However, the sustainability of SGI is an important factor to be kept in mind as bad experiences in South Asia, the Middle East or in North Africa show (Comprehensive Assessment of Water Management in Agriculture 2007).

Crop disease is a factor that also affects SGI negatively. In the absence of any extension services, farmers rely heavily on trial and error when it comes to the treatment of plant diseases. The lack of expertise and adequate pesticides leads to significant crop losses. In the dry season of 2003-04, for instance, a tomato disease hit the UER, and hundreds of hectares of tomato farms, both in formal schemes and in areas with SGI, were destroyed (News in Ghana, 2004). Despite this crisis, which ruined quite a number of farmers, the area farmed in the following dry season hardly decreased.

Marketing problems and regional as well as global competition threaten the profitability of SGI and its adaptive capacity the most. Tomatoes are mainly produced for the fresh tomato market in southern Ghana. The produce is bought by female traders from southern Ghana, who buy from the farm gate. In good years the relationship between farmers and market ladies is – despite some bickering about prices on both sides – relatively good. Prices vary a lot though, as at the beginning and the end of the harvesting season demand outstrips supply, while at the height of the harvesting season tomato gluts often lead to the collapse of market prices. The tomato ladies are highly organized and they are known to be able to engage in concerted action (Clark 1997). If they feel farmers' prices are too high, they stop buying tomatoes, forcing the farmers to sell their produce at lower prices, due to its perishable nature.

In the past, market failure only occurred occasionally, especially during gluts. But local tomato marketing has become increasingly difficult over the last couple of years. Burkinabè vegetable producers who lost their market in the Ivory Coast during the civil war started to attract Ghanaian traders, who started to import tomatoes from Burkina Faso. Imports into Ghana increased from under 18,000 tons in 2004 to up to almost 80,000 tons in 2006 (Awo 2007: 27). Market ladies increasingly bypass the tomato producing areas in Northern Ghana. They claim that lower prices and better quality make tomatoes from Burkina Faso more attractive. However, farmers and officials in the UER maintain that it is side businesses such as the sale of fruits, timber and drink – as well as the smuggling of petrol, cloth, gold or even drugs – that drive the traders to Burkina Faso.

In 2007, the situation escalated. The traders completely ignored tomatoes in the UER and drove almost all their trucks to Burkina Faso, leaving the tomatoes of the Ghanaian farmers rotting. This led to bitter protests, roadblocks and the waylaying of tomato trucks on their return from Burkina Faso. As the Economic Community of West African States (ECOWAS) regulations grant the free exchange of goods, the Ghanaian government blamed farmers in Burkina Faso for using harmful substances in the production of tomatoes, and blocked the border for two weeks. The government urged the tomato ladies to also buy tomatoes from Ghanaian farmers, which they did reluctantly. However, most of the Ghanaian farmers had already experienced great losses. Their losses were particularly large as the government promised farmers before the beginning of the growing season that an old tomato factory at Pwalugu, which had collapsed in the 1980s, would be reopened and purchase large amounts of the farmers' produce. Consequently, many farmers substantially increased their production. But the factory only started buying tomatoes when the season had almost ended.

In 2008, the tomato market was extraordinarily good, but demand outstripped supply. Many farmers lacked the necessary capital to farm, due to the marketing problems in the year before and because they lost most of their rainy season crops due to a combined impact of drought and flood in the rainy season of 2007/08. Burkinabè farmers had also incurred substantial losses during the time the border had been blocked by the Ghanaian government. They therefore switched part of their production to other vegetables and phased their tomato production in a way that they would hit the market when Ghanaian farmers had already gone out of production. At the same time, the demand for tomato increased as the tomato factory finally started purchasing tomatoes in 2008. Many farmers were content that the factory was now running, but the prices it offered were low, which meant that the farmers only sold those tomatoes to the factory that the market ladies refused to buy.

The reopening of the Pwalugu tomato factory has been the object of the hopes and dreams of many peasants in the research area since long. They feel that a steady demand for tomato granted by the factory could help to solve their marketing problems. Politicians have frequently tried to profit from this hopes and promised to look for

international investors or to use government funds to rehabilitate the tomato factory. However, to profitably produce tomato paste in northern Ghana proves difficult. The factory can only offer extremely low prices to the tomato producers as it has to compete with producers from Europe, America and Asia that exported cheap tomato products into Ghana. Since 1998, Ghana has seen a major import surge in tomato products. Imports increased from 3,300 tons in 1998 to 24,740 tons in 2003, an increase of 650 per cent. Consequently, the market share of local tomatoes fell from 92 % to 57 % (FAO 2006: 2). According to FAO (FAOSTAT 2008), imports of tomato products increased further to 96,000 tons in 2005. In between 1999 and 2003, major exporters of tomato paste to Ghana came from the EU (54 %, mainly Italy), China (16 %), USA (8 %), Turkey (7 %), and Chile (5 %) (FAO 2006: 2). Exporters are able to offer cheap tomato products because of a high degree of mechanization and economies of scale, as well as high agricultural and export subsidies. In the EU, for instance, between 2001 and 2008, the production of processing tomatoes was subsidized by 34.50 € per metric ton, which amounted to approximately 50% of the growers' prices and producers' turnover (Bunte 2007: 6, FAO: 2). Additionally, exports from Italy in 2001, for instance, were supported by EU export refunds of 45 €/ton (about 10 per cent of wholesale prices) (FAO 2006: 2). China, which has seen an extreme rise in processing tomato production over the last few years, has also introduced subsidies for tomato production since 2007, and tomato paste exports are facilitated by the artificially low exchange rate of the Yuan against the USD (Zhang et al. 2010: 43, 73). Conversely, agricultural subsidies in Ghana have been abolished since the structural adjustment programs (SAPs) of the early 1980s, and farmers have found it difficult to compete with low international prices. International competition curtails the national demand for fresh tomatoes, and puts pressure on real prices in Ghana, which have also declined against the prices of agricultural inputs (Amikuzuno 2010: 113). As part of the of the structural adjustment programs introduced by the Bretton Woods institutions in 1992 protective import tax policies were abolished in Ghana and the import tax for agricultural products has been fixed at 20 % (Robinson and Kollavali, 2010: 2). Given the high subsidies for tomato production, processing and exportation the current import duty does not create a leveled playing field for Ghanaian tomato producers and processors. Thus, international competition and global terms of trade render tomato processing in Northern Ghana unprofitable. The tomato paste factory in Pwalugu, which was reopened with considerable government funding in 2007, operated fully in 2008, the year of the national elections, largely reduced its operations in 2009 and never operated in 2010. In 2011, after some political pressure the factory started buying tomatoes by the end of the season. However it could not provide transport and many farmers were not able to carry their tomatoes to the factory. The factory, once again seems to function as political bait for the upcoming presidential elections in 2011, but the de facto closure of the factory leaves local tomato farmers without access to processing facilities and alternative market channels. The unfair conditions of international, regional and national tomato (product) trade largely limit the adaptive capacity that tomato production under SGI could have. Similar drawbacks of SGI can be observed in the onion growing areas close to Bawku. Since onions are not as perishable as tomatoes, farmers can avoid gluts by storing their produce. However, marketing cartels as well as regional and global competition lead to low prices and potential losses for local farmers (Blench 2006: 4).

7 Conclusion: Double exposure and the perils and promises of local adaptation

This paper set out to show how the double exposure to (global) environmental change and economic globalization affects peasants in Northern Ghana. The research area

belongs to the poorest region of Ghana, with more than 80% of the rural population having an income below the official poverty line. Apart from persistent poverty, the area is affected by severe environmental change. The degradation of natural resources is partly the result of local dynamics such as population growth, poverty and unsustainable resource exploitation, which are aggravated by a framework of international and national policies that inhibit the intensification of rain-fed agriculture, but are also caused by the impact of global climate change that has started to affect the local climate.

Faced with unreliable environmental and changing economic conditions, local small-scale farmers have developed diversified livelihood strategies that range from hunting and gathering, fishing, agro-pastoral production, mixed cropping and (petty) trade to (migrant) wage labor. Adaptation in the realm of agricultural production is derived through the adoption of new rainy season crops, changes in rainy season cultivation patterns and the expansion of SGI. Peasants in the Atankwidi and Anayere catchments, using SGI techniques, have begun to expand the production of marketable vegetables to adapt to changing environmental conditions that render their rainy-season farming increasingly risky and unproductive. The advantage of farmer-driven SGI is its local social, cultural and institutional embedding. The sharing of land, labor and knowledge among farmers makes SGI a technology that is comparatively easy to adopt – even by poor farmers. Furthermore, SGI has positive adaptive effects for many practicing small-scale farmers, and results in higher food security and standards of living.

Nevertheless, SGI has certain risks and limitations as an adaptive strategy, as crop diseases and water shortages affect the yields of tomato production and sometimes endanger the whole harvest.

The largest threat to the local irrigation economy, however, is neither a diminishing resource base nor imperfect agricultural practices. While farmers try to integrate in the larger economy in order to overcome poverty and to adapt to environmental changes, they become subject to market failures that are partially the result of monopolistic local market channels, but are also in their essence caused by unfair and unpredictable patterns of global trade and economic policy prescriptions by international lending organizations.

Like many other internationally promoted development efforts and initiatives for economic growth, the local peasants attempt to adapt to changing environmental and economic conditions is doomed to failure under the prevailing macro-economic conditions of global markets. This case study therefore, also emphasizes that the double exposure to global environmental change and economic globalization, the intensification of trade and the falling of political barriers towards trade (at least in the south), need to be taken into consideration when local adaptive capacities are discussed. Being adversely affected by global environmental changes they have little contributed to, peasants in northern Ghana and beyond are bereft of the few possibilities to locally adapt to a changing environment by economic conditions created by the very countries contributing the most to global environmental change.

Many convincing arguments call for the revision of unfair and discriminatory economic practices and terms of trade; however, the need to enhance adaptive capacity towards global environmental change for poor parts of the population in the south should be added.

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