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THE IMPACTS OF CLIMATE CHANGE UPON FOOD SECURITY IN THE WORLD. THE INTERACTION BETWEEN PHYSICAL, BIOLOGICAL AND SOCIETAL SYSTEMS

LOS IMPACTOS DEL CAMBIO CLIMÁTICO, SOBRE LA SEGURIDAD ALIMENTICIA EN EL MUNDO. LA INTERACCIÓN ENTRE SISTEMAS FÍSICOS, BIOLÓGICOS Y SOCIALES

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ABSTRACT

In this paper is brought forward certain scientific research for showing the physical and biological premise for our discussion. Secondly, it is wanted to show the necessity of linking physical and biological processes with societal practices for understanding how physical, biological and societal systems interact with each other. The third purpose of the paper is to show how those current conditions, processes and interactions affect global food security.

Keywords: Food security, climate change, physical processes, biological processes, societal practices.

RESUMEN

En este artículo se recolectan algunos trabajos científicos que apoyen las premisas físicas y biológicas para nuestra discusión. En segundo lugar, se desea mostrar la necesidad de conectar los procesos físicos y biológicos con las prácticas sociales, para entender cómo los sistemas físicos, biológicos y sociales, interactúan entre sí. El tercer propósito de este artículo es mostrar cómo las actuales condiciones, procesos e interacciones afectan la seguridad alimenticia global.

Palabras clave: Seguridad alimenticia, cambio climático, procesos físicos, procesos biológicos, prácticas sociales.

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BACKGROUND AND PURPOSE

In order to meet a growing population's demand for food, fuel, fibre and timber, man has, in the last fifty years, altered the ecosystem at a rate unprecedented in human history. Out of the 24 ecosystem services studied in the Millennium Ecosystem Assessment (2005), 15 are already today degraded or used in a non-sustainable way.

Examples of such degraded ecosystems are the air quality, the rainfall and water quality, the erosion control, the detoxification of waste products, the natural protection against environmental disasters (such as for example mangrove and coral reefs), the control of diseases and plagues, pollination and marine systems. Several of these systems interact with each other and have a direct impact on food security.

Climate change can moreover directly and indirectly affect food security. Heat can affect crop yields. Storms and floods can not only affect crops directly but also, indirectly, by means of soil erosion. Marine organisms may be adversely affected by a combination of too much fertilizer being used in agriculture, rising water temperatures and a low pH value – which in turn is, to a large extent, a product of high concentrations of carbon dioxide in the water. The interactions are many in numbers and the product of physical and biological processes as well as of societal practices.

This paper has three purposes. Firstly, it aims to bring forward certain scientific research results in order to show the physical and biological premise for our discussion. Secondly, it wants to show the necessity of linking physical and biological processes with societal practices in order to understand how physical, biological and societal systems interact with each other. The third purpose of the paper is to show how those current conditions, processes and interactions affect global food security.

In order to fulfil these purposes, the paper has been structured as follows: After a presentation of certain *methodological considerations* which form the basis of our argument, and following a brief review of FAO's *Basic concepts and categories,* the section *The relationship between physical, biological and societal systems* focus upon examples of interactions between different systems. The purpose of this section is not only to highlight these correlations but moreover to present important research findings within the field of natural science; this is also done in the following section, where we discuss *Forecast* of crop yield.

In the second part of the paper, *Climate change and food security: Societal and cultural considerations,* we discuss more specifically the various social factors that affect food security, especially the global markets. Together with the previously presented scientific results, this part is intended to highlight the key factors which affect global food security.

In the *Final discussion* we clarify how the concepts and arguments presented in the section *Methodological considerations* can help us understand various processes and connections by means of raising awareness about nonlinear course of events, positive feedback mechanisms and emergent phenomena. Within this context we also emphasize the need to integrate the physical, biological and social systems.

METHODOLOGICAL CONSIDERATIONS

The notion of "system" here refers to an analytical category and provides a construction which we can use to identify interactions within a specific time and place. For this we employ Complexity Theory according to which a system should always be studied both in itself and in relation to other systems. Complexity Theory studies complex systems, in our case the food security. The theory assumes that a whole consists of properties which are not to be found in any of the separate components. These properties have emerged in a specific time, at a specific place and have not always been foreseeable (precisely because they did not exist within the individual components). This phenomenon is called "emergence" and may be either the result of the interaction between the systems' various components or of the interaction between the system and the environment (Bar-Yam, 2000).

Within complex systems, many different agents interact with each other, either directly or indirectly. These systems are characteristically non-linear which means that the relationship between two variables is not proportional (Bar-Yam, 2000) or that the response to a particular agent is not proportionate to that agent (Steffen et al, 2004). We can not extrapolate a line based on the variables known to us. Once the phenomenon has reached a certain point a minimal input may be enough to cause a major impact; when the system reaches such a "bifurcation point" the system is transformed and new structures and organizational principles arise.

Feedback mechanisms – a key process within complex systems – can be defined as the processes during which the effect of a phenomenon or event influence the agents which initially caused that particular effect (Bar-Yam, 2000; Thrift, 1999). Such processes hence preclude the stipulation of a direct cause and effect-relationship; the "effect" may be that which gave rise to the change which, in turn, came to influence what then took place. One example of a positive feedback mechanism (the mechanism which triggers the process) is to be found within the relationship between plants and climate. Parts of that process can, somewhat simplified, be described as follows: plants give off water; this water vapour is then brought back into the atmosphere where it forms clouds; these clouds affect the sunrays' ability to reach the plants and thus, indirectly, affect the plants' growing potential. The constitution of the clouds, the configuration of the land, the biological processes, the atmospheric radiation and the atmospheric dynamics are all factors involved in this process. They interact in multiple ways, both in different time periods and in different places. A very small change in any of these factors may have enormous consequences for the plants' growing ability (Rind, 1999).

BASIC CONCEPTS AND CATEGORIES

In order to get a general picture of the food security we employ some of FAO's (Food and Agriculture Organization of the United Nations) dimensions of food security: food availability, food accessibility and food utilization (2008).

Food availability refers to the amount of food being produced, processed and manufactured, distributed and commercialized - including imports but excluding exports. *Food accessibility* refers to the various communities' and individuals' legal, political, economic and social possibilities to obtain food. *Food utilization* refers to mans' physiological capacity to transform the food he eats into energy as well as to his intellectual conditions in terms of being able to choose and prepare the right food.

The relationships between these different factors are multiple and belong to various societal, biological and physical systems. For example, food accessibility is connected to political economy (a societal system) and food availability, amongst other things, to temperature and to the possibility of pollination (a physical and biological system respectively). Food accessibility and food availability then, in turn, interact with each other and affect food utilization (which can be studied both within a societal system and within a biological / physiological system). Food security can be said to depend upon the interaction between a societal, a biological and a physical system.

THE RELATIONSHIP BETWEEN PHYSICAL, BIOLOGICAL AND SOCIAL SYSTEMS

Climate disasters affect agriculture in that they can lead to crops and infrastructures being destroyed. But they can also result in fewer employment possibilities as agricultural land risk being destroyed by floods or drought; in wages decreasing when the job seekers outnumber the job opportunities; and in food prices rising as the food availability is reduced. History has shown that poor people fighting for their survival get into difficult situations as they may find themselves forced to sell their animals (to an all too low a price since everyone is selling at the same time) and to turn to crime and/or prostitution – this was, for example, the case in Malawi 2002 when the drought left five million people in need of food assistance (UNDP, 2007/2008: 84).

Agricultural crises also bring about long-term effects for both individuals and for entire countries. Drought and floods have been shown to lead to undernourishment as both food availability and food accessibility decreases as a result of poor crops and increasing prices. The drought in Kenya 2005 left approximately 3.3 million people at risk of starvation. Earlier periods of drought, in 2003-2004, led to undernourishment among children increasing from 6 to 30 per cent in Kajiado, one of the country's hardest hit areas (UNDP, 2007/ 2008: 86-87).

When families in India have been forced to reduce food consumption, it has been shown that the girls more frequently get to suffer from undernourishment than the boys, and that more girls than boys die during periods of drought. Poor families have been forced to take their children out of school in order to have them helping supporting the family; examples of this has been found in Ethiopia, Malawi, Bangladesh and India as well as in Nicaragua where the number of working children rose from 7.5 to 15.6 per cent in the wake of Hurricane Mitch. The same hurricane resulted in the poor rural households in Honduras loosing 30-40 per cent of crop revenue, and national poverty rate rising from 69 to 77 per cent (ibid.).

Undernourishment leads to greater susceptibility to disease and therefore to lower incomes which, in turn, prevents the poor from seeking treatment. In a survey conducted in central Mexico to study the impact of the drought hitting the country in 1998-2000, it was discovered that the drought had increased the likelihood of a child below the age of 5 to fall ill by 16 per cent. The survey also looked at the probability of falling ill after a flood and the results showed a corresponding increase of 41 per cent. (ibid.). A survey in Zimbabwe studied a group of children who had been 1-2 years old during different periods of drought (1982-1984). These children, now 14-18 years old, showed to have started school later than usual (due to helping supporting the family) and to have had 0.4 years less schooling. It was estimated that these children – due to their shortened education and general health impacts – would have 14 per cent lower total earnings (UNDP, 2007/2008: 88).

The United Nations Development Programme, which was behind the Human Development Report 2007/2008, triggered studies on the effects of drought on the development of children born during dry seasons in Ethiopia, Nigeria and Kenya. These studies found that Ethiopian children under the age of 6 – that is, children born during, and affected by, dry periods – had a 36 per cent higher likelihood of suffering from undernourishment and a 41 per cent higher probability of being chronically undernourished (stunted). In Kenya, the figure for probable undernourishment in children was 50 per cent and in Nigeria, children under 2 years old (i.e. children born during a dry period) were 72 per cent more likely to be stricken with chronic undernourishment (UNDP, 2007/2008: 89).

The need to integrate the social and natural sciences, and the systems contained within each of these disciplines, also becomes obvious when we, for example, look at the human suffering in the Sahel area of Africa, where millions of people today are in urgent need of food assistance. This story began during the 1960s and 70s, when the rich countries' emissions of sulphate aerosols led to temperature differences between the North Atlantic regions and the tropical regions, as well as between the atmosphere and the ocean surface. This affected the North African monsoon system: the amount of rainfall in Sahel declined and the soil was degraded; these environmental problems, in turn, impaired the political difficulties in the area (Rotstayn and Lohman in Steffen et al., 2004). In south Sudan alone, twenty years of conflict has resulted in approximately two million people having died. Sudan is moreover at the top of the list of countries receiving food assistance from the UN: two million food rations per month (UNWFP, 2010).

Climate change affects weather patterns in that it brings about changes in winds, storms, temperature, humidity, and drought, as well as in the amounts, intensity and frequency of rainfall. These changes, in turn, have an impact on what type of vegetation that can grow in different zones, on the yield of crops (cultivated, edible plants) and of wild plants, on the biodiversity, on the pastures, on the various types of plagues and diseases, on the beginning and end of the growing season and on the shift in the climatic zones. The weather patterns moreover affects soil erosion, water and nutrient cycles, soil salinity (which is interconnected to soil dryness) and coastlines. All these factors, in turn, have a major impact on the ability to grow grain, fruit and vegetables, i.e. on food availability. As wheat, maize and rice account for approximately half of the calories consumed by the world's poor, a decrease in this grain production would have disastrous consequences (Lobell et al., 2008a).

Crop production appears to decrease when the temperature rises, more specifically by about ten per cent per each degree exceeding 26ºC. The relationship between crop yields and temperatures above 30ºC is moreover of a non-linear character; beyond this point yield is reduced even more significantly (Lobell et al., 2009: 5, 12).

The concentration of carbon dioxide could potentially increase the crop yields in the temperate regions but this is highly dependent upon temperature and nutrient availability (Hodson and White, 2009: 53-54, 59).

A study at Ohio State University shows that the photosynthesis begins to decrease at 35 °C only to cease completely at 40 °C (Brown, 2008: 52). A reduction of the photosynthesis means that plants will stop growing, a termination of the photosynthesis means they will die.

In the summer of 2003, the mean temperatures in Europe rose 6 °C above normal. This resulted in Italy's maize yield decreasing by 36 per cent and France's yield of fruit and forage decreasing by 25 and 30 per cent respectively (FAO, 2008: 21).

A rise in temperature and an increase in carbon dioxide concentration moreover affects the quality of wheat: wheat's protein content is lower in a system with low nitrogen content (Hodson and White, 2009: 57-58). This may lead to a reduction in the protein intake among the world's poor and to poor countries having to reduce the price on their crop in order to be able to sell it.

Tubiello et al. (2007) argues that food accessibility has not so much to do with crop yields but rather with socio-cultural factors and the number of cultivated acres; with inverted capital and inverted labour; and with technological and economic development. Tubiello is right in claiming that food accessibility is subject to these other factors as well, but not in proposing that food availability would play only a minor role. There are not an infinite number of hectares suitable for agriculture and which can be used without, at the same time, destroying essential ecosystems such as forests and wetlands. The lack of agricultural land has become apparent in recent years as certain countries now buy or lease land overseas in order to be able to supply their populations. One of the socio-cultural factors which Tubiello et al. *fails to mention and/or exemplify* is the major corporations' short-term profit-making interests. For example, mechanical degradation of soils lead to a short-term increase in soil fertility as the process involves soil nutrients becoming mineralized (i.e. organic matter is being transformed into non organic matter which makes it easier to absorb for plants). In the long run, however, the effect is the opposite. Repeated ploughing destroys the structure of the soil; the soil becomes more compact, erosion increases and the soil is being deprived of its nutrients (FAO, 2008). Tubiello et al. also assume that market economy and liberalization function well in the sense that global trade ensures food being transported from those countries in which climate change has had a positive impact to those in which it has had a negative impact. This is not, however, how it works today and, for historical reasons, we doubt this is how it is going to work in the future.

Marine ecosystems are affected by climate change, by overfishing, by pollution, by pesticide and fertilizer use, by changes in the use of land, by stormwater management and by raw sewage. All these factors interact with each other. Climate change affects ocean organisms by means of a rise in water temperatures and by an increase in water acidity - a result of rising levels of carbon dioxide in the oceans and of solar radiation.

Most marine organisms have their habitats in the oceans' upper water layer which is brighter and richer in food. These organisms' food chain begins in small photosynthetic organisms (phytoplankton) which, in turn, get their nutrients from the depths of the ocean. The warmer surface water the greater the difference between the oceans' top and bottom water layers. The upper, warmer layers prevent the nutrients contained in the depths to surface, which means less food for the plants and algae at the base of the food chain (Caldeira, 2007). During the last century, the amount of phytoplankton has decreased (Boyce et al., 2010). As the 20th century has seen a water temperature increase of approximately 1°F (0.55 °C) (Eakin, 2007) and this has affected food availability and fish physiology, some fish stock have had to relocate to cooler areas. This was for example the case in Namibia in 1995, where, in connection to the El Niño phenomenon (the cyclical warming of certain parts of the Pacific Ocean surface water), fish stock had to shift 4-5° degrees south latitude and thus thwarted small scale fishermen's livelihoods (UNDP, 2007/2008: 104).

Scientific forecasts indicate that the ocean acidification processes will continue. If the carbon dioxide concentrations in the atmosphere has reached 500 ppm in 2050, and 800 ppm at the end of 2100 (which the IPCC's forecasts show is indeed possible), this means that the oceans' surface waters have become more acidic than they were over 20 million years ago. The water acidity prevents the coral reefs' skeletal formation, impairs the ability of those marine organisms serving as food for salmon, mackerel, herring, cod and pollock to produce the protective shells they need for their survival, and affects the fish' respiration rate, chemical composition of the blood and enzymatic activity (Feely, 2008). The coral reefs are also affected by solar radiation and rising water temperatures. During long periods of stress, the coral tissue repels the algae which lives in symbiosis with the coral as well as gives it its colour; this results in the coral becoming more susceptible to illness and in some cases in it dying. Today 20 per cent of the world's coral reefs have died and another 20 per cent are degraded (WRI, 2005: 2). According to IPCC forecasts, this trend will continue growing unless the corals themselves find a way to develop some sort of adaptation mechanism (Eakin, 2007). If the coral reefs disappear, so will many of the marine organisms for which the reefs serve as habitat. Moreover, the coral reefs provide the livelihood for approximately thirty million small scale fishermen in the developing countries, as well as constitute an important source of economic development in more than 60 countries in the world (UNDP, 2007/2008: 104).

FORECASTS OF CROP YIELDS

Today approximately 1.4 billion people live in areas with water problems caused by falling groundwater levels and reduced rainfall. Climate change may result in an additional 1.8 billion people having ended up in this category by 2080. According to climate models, a 1 °C increase in temperature will, already by 2020, have resulted in water supplies in Overgha, Morocco being reduced by 10 per cent. The same climate models foresee a 50 per cent decrease in Syria's renewable water supplies over the period 1997-2025 (UNDP, 2007/2008: 95). Scarcity of water means scarcity of agricultural produce and, for the poor countries, scarcity of food.

Today's largest cultivated land surfaces are to be found in eastern US, eastern Latin America, Europe, South Asia, Southeast Asia and East Africa south of Sahara (WRI, 2005). The areas which will be most affected by the drought is the American Southwest and the African Sahel region - a region stretching from the Atlantic to the Indian Ocean, more specifically from Mauritania and Senegal in the west, to Sudan, Ethiopia and Somalia in the east (Brown, 2009: 71). As the US is one of the world's main producers and exporters of grain, a decrease in the country's crop yields may affect prices all over the globe. A reduction of crop yields in abovementioned African countries may result in famine, political unrest and mass migrations.

Climate models predict a 3 - 4 °C increase of temperature in India this century. The country's crop yields are expected to decline by 1.5-5.8 per cent in the subtropical regions and by even more in the tropical regions (Hodson and White, 2009: 57). In Bangladesh, a four-degree increase in temperature is estimated to reduce rice and wheat production by 30 and 50 per cent respectively; in Indonesia, rice and corn yields are calculated to have fallen by 4 and 50 per cent respectively by 2050 - the most significant reductions are expected to be found on the coast as a result of contaminated seawater. In parts of Latin America, the situation is equally critical: Latin American and Mexican small scale farmers' corn yields are feared to decrease by 10 and 60 per cent respectively. In Brazil, on the other hand, the corn yields are expected to increase by 25 per cent. Impoverished farmers dependent upon rainfall are the ones most affected; big-scale, wealthy farmers with modern irrigation systems do much better. (UNDP, 2007/2008: 94).

Information on areas south of the Sahara shows that by the year 2030, corn yields will have dropped by 30 per cent in comparison to the production in 1990 (Lobell, 2008b). In North Kurdufan, Sudan, the temperature is estimated to increase by 1.5 °C during the period 2030-2060; rainfall is estimated to decrease by 5 per cent. This may bring about, among other things, a 70 per cent reduction in the millet yield (UNDP, 2007/2008: 92). It is not difficult to imagine that climate change will have devastating consequences for a country like Sudan, a country whose population has increased from 9 to 39 million people between the years 1950 to 2007 (Brown, 2008: 118); a country where 4.9 million people in 2009 were put to flight in their own country due to conflict and environmental problems such as droughts and floods (UNDP, 2009: 26; UNWFP, 2010); a country in which the population - despite receiving United Nation World Food Programme's largest food assistance has to resign to the fact that its own farmland is being bought or leased by the world's rich countries (UNWFP, 2010).

The US produces 41 per cent of the world's corn supply and 38 per cent of the soybean supply. A decrease in this production may have implications for the availability of these crops throughout the world. Drawing on the US Department of Agriculture's statistics on US yields of corn, soybean and cotton during the years 1950-2005, Schlenker and Roberts (2009) anticipates how, given IPCC's lowest scenario - i.e. a 0.6 °C increase in the mean temperature - the US will see a 30-46 per cent reduction in these yields during this century. Given instead the IPCC's highest scenario – i.e. a 6.4 °C increase in the mean temperature – the corresponding figures will be 63-82 per cent.

The production of crops is affected not only by heat and drought but also by floods. Vietnam is the world's second largest rice exporter; more than half of its production is located in the Mekong Delta (Brown, 2009: 7). Already in 2030, about 45 per cent of the area is estimated to have been affected by salt water and by flooding, something which could result in the area's rice production decreasing by 9 per cent. At a water level rise of one meter – something which is expected to have occurred by year 2100 - the whole area will at times be under water. The 4 million impoverished farmers living and working in the area are facing undernourishment, health problems and insufficient schooling for their children as these will be forced to help with family support (UNDP, 2007/2008: 100).

CLIMATE CHANGE AND FOOD ACCESSIBILITY: SOCIETAL AND CULTURAL CONSIDERATIONS

Our ability to obtain food (food accessibility) is due to several different factors such as for example whether the household can grow its own food, whether there is food to buy and whether the price of food is feasible. Whether or not there is food to buy has, in turn, to do with the amount of food being produced, stored and transported, and with political-economic measures on a national and global level (ability to import and export). All these factors influence the price of food on the open market. Whether or not people can afford to buy these products has to do with the household's ability to earn enough money, either through employment, through self-employment or through other financial practices (primarily in rich countries).

Food access thus expresses itself in different ways for those people living in a rich country than for those living in a poor, just as it expresses itself differently for farmers growing mainly for their own consumption than for people living in a city.

For those poor countries which themselves produce most of the food the inhabitants consume, a reduction in food supply can lead to a reduction in the quantity of food consumed and therefore a reduction in the number of ingested calories. This means that, depending on culture, all family members get less to eat or that the food available is given to the adult males who are expected to need more to be able to support the family (FAO, 2008).

In richer countries, a reduction in food availability may result in a change in social behaviour. People may begin to accept scarcity of food in some parts of the world as something natural; development assistance and other types of aid to the poor may be questioned if it means that the rich countries must refrain from what they regard as important. The rich farmers producing for trade and in large quantities tend to protect themselves against production losses through various types of insurance. This is not the case for the small scale farmers in developing countries who are rarely or never insured; a poor harvest inevitably means that they have lost their source of income and therefore also their means to obtain other products on the market (FAO, 2008).

Climate change may also affect the infrastructure necessary for storing and transporting food. Storage rooms, power lines, roads, etc., can be destroyed due to floods, tornadoes, hurricanes and the like. An increase in temperature and atmospheric humidity can destroy crops during harvesting and storage since such conditions accelerate the reproduction of microorganisms and therefore also the destructive processes triggered by these. Producers in countries with poor infrastructure and insufficient financial resources may fail to reach both local and global markets. Reduced food accessibility leads to an increase in prices which, in turn, may force people to reduce their consumption. An extreme price increase may cause political demonstrations and civil unrest; an example of this was seen in Mexico in 2007 where 75 000 Mexicans took to the streets in a protest against the 60 per cent increase in the price of tortillas (made from corn) (Brown, 2008:40).

HOW SOCIETAL PRACTICES AFFECT FOOD ACCESSIBILITY: THE GLOBAL MARKETS

In a world where the climate is changing – and thus the crop yields are changing – it is sometimes assumed that the global food trade can mitigate the effects of food shortages in those countries worst affected. This argument is based on the notion that whatever cannot be produced in one country can be produced in another and then, through trade, distributed wherever needed (so-called comparative advantages). Trade liberalization is here moreover assumed to, by means of competition, help reducing costs (Nelson et al., 2009). That comparative advantages and liberalization work in an ideal world but not in the real one is made clear in the Human Development Report 2005 from the UN Development Programme (UNDP). A country's export is generally an important source of income when it comes to financing the import of new technologies, technologies which, in turn, generate development. Exclusion from the world markets means exclusion from technology and as such is therefore an obstacle to further development; in order for the developing countries to have any use of international trade, they must get access to the rich countries' consumers. In reality, however, the high-income countries (whose populations constitute a mere 15 per cent of the total world population) account for two thirds of the exports in the world. In terms of exporting manufactured goods – goods whose added value is the most relevant when it comes to combating poverty in exporting countries – the industrialized countries account for more than 70 per cent of this export (UNDP, 2005). How can this be?

When speaking of the developing countries' difficulties in participating on the international markets, the UNDP points out three main obstacles: the system of tariffs preventing imports; the rich countries' system of subsidizing their own production as well as their export; and the World Trade Organization's (WTO) industrial policy and rules on intellectual property and patents.

The industrialized countries impose higher custom tariffs on products imported from developing countries than on products imported from other industrialized countries - in some cases up to three or four times higher. Industrialized countries also impose higher custom tariffs on manufactured products than they apply on raw materials; as already mentioned, this works against the developing countries as it is precisely such products that are of great importance when it comes to these countries' further development opportunities. Since many poor countries are economically dependent upon the revenue from the custom tariffs they themselves put on imported goods, they also come to put high tariffs for trade among themselves.

Many of those countries belonging to the Organization for Economic Cooperation and Development (OECD) – that is, high-income countries – give subsidies to their own farmers, subsidies equivalent to 1/3 of the production costs. This practice is usually justified by reference to the need to develop the country's rural areas. In reality, however, and which studies and statistics show, it is not the small scale farmers out in the countryside who receive this financial assistance, but rather the large scale landowners and the industrial companies. 40 per cent of the EU budget goes to the agricultural sector – a sector which employs less than 2 per cent of the total labour force – and ¾ of the support from the CAP (EU Common Agriculture Policy) is divided amongst the top ten per cent of the largest receivers. The EU subsidies for sugar exports, for example, resulted in global prices decreasing by approximately 1/3 in the early 2000s. For comparison: the rich countries spend just above $ 1 billion per year on assistance to agricultural development in the developing countries; they spend just below $ 1 billion *per day* on assistance to domestic production (ibid).

United Nations Development Programme (UNDP, 2005: 117-135) concludes that the system of subsidies means that the agricultural global markets are not being determined by the comparative advantages (which would be the case in an ideal world) but instead by the possibility of obtaining subsidies. Subsidies make it impossible for small scale farmers to compete both globally and locally. In times of surplus production, prices on the international markets fall too much, cutting out the farmers in developing countries.

In connection with the 2007-2008 vast global increase in food prices (when, for example, the price of rice tripled) it became apparent that individual countries, in times of crisis, may take drastic measures to insure their own country's food supply and thus, hopefully, prevent political unrest. These measures meant that producing countries came to regulate their grain exports; in reality this meant that exports decreased and that importing countries, in panic and through bilateral agreements, bought huge amounts for future needs. The price increase was thus not just an effect of a reduced grain supply, but also of a decrease in export (Headey, 2010). The heat wave and the fires raging across much of Russia's wheat plantation in the summer of 2010, resulted in the country having to reduce their wheat exports, something which in turn meant that the markets, in June alone, saw a 50 per cent increase in the price of wheat (Financial Times, Aug 3, 2010).

For the last three years, food-importing countries have shown doubt in trusting the global markets' capacity to solve potential food crisis (caused by agents such as climate change, water problems, soil erosion, population growth, changed eating habits, use of grains for biofuels, etc.). These countries have now – either via their governments or via private companies – started to buy or lease farmland, mainly in developing countries, in order to assure future food supplies. Examples of this can be seen in the United Kingdom's interests in Kurdistan; South Korea's in Madagascar; Saudi Arabia's in Thailand and Sudan; China's in the Philippines and Sudan; India's in Mongolia, Ethiopia, Senegal, Tunisia, Sudan and Argentina; the US's in Sudan and Laos; EU's in Ethiopia; and Denmark's, England's and China's interests in Russia. These countries, alternatively companies in these countries, have either already bought or leased agricultural land for 99 years to come or are currently in negotiations to do so (http://farmlandgrab.org. 10-04-13 and www.grain.org 10-04-13).

If the agricultural trade has proven not to work in relatively stable times, it is difficult to imagine that it will work during situations of global crises such as those caused by a decrease in food availability.

FINAL DISCUSSION

Scientific research has indicated that the impact of heat on the yield and quality of crops, and the impact of acidity and water temperature on coral reefs and other aquatic organisms are of nonlinear nature. When temperatures on land have reached a critical point, crops will stop growing and die. When the temperature rises in the oceans, or when the acidity of the water has reached a critical point, various organisms stop evolving and the whole food chain is affected. Reductions in crops or in marine organisms have different social implications for different groups of people in the world.

Production may affect distribution: a decreased production means a reduced distribution (given there are no food reserves). Food utilization can affect yield and purchasing power by various positive feedback mechanisms: if agricultural workers do not consume adequate amounts of food or do not get the nutrients they need, they risk becoming ill and thereby not able to continue producing; if other workers (i.e. non-agricultural workers) become ill for the same reasons, they will lose their income and thus their purchasing power. Food being prepared without regard to hygiene can cause contamination which, in turn, may affect peoples' working capacity and ability to obtain food.

Distribution man affect food utilization: if food transports are forced to travel on substandard roads, it may lead to the food being destroyed alternatively not delivered to the people in need. Instability in the system can cause the appearance of emergent phenomena such as migration and conflict in the struggle for resources. How large or severe these phenomena may be is difficult to predict. In order to study food security in the context of climate change, we need to integrate the physical, biological and societal factors. We also need to think in terms of non-linear systems and to reflect upon the emergent phenomena possibly appearing when the biological or societal systems have reached a bifurcation point. Furthermore, we need to study the positive feedback mechanisms which are triggered between the different components of the food system.

The greater the number of undernourished and ill people in a country, the less chance that country has to get out of poverty. Undernourishment and disease affect people's possibilities to educate and support themselves; failing to provide for themselves, in turn, leads to undernourishment and then the viscous circle is complete. The effects of climate change on different societies depend upon the societies' perspectives on issues relating to economic development, infrastructure, health care, education and, not least, upon how wealth is being distributed: the poorer the society, the more serious the consequences.

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