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Noodles at any Cost: Food Self-Sufficiency and Natural Hazards in China

Elisabeth Simelton[1]

Abstract

China's role on the global grain market is expected to increase as the demand for food and feed grows, both within and outside the country. This role could also be affected by unexpected crop failures caused by natural hazards. This paper uses agricultural production (rice, wheat, maize, tubers, soybeans and other grains) and natural hazards data (floods and droughts) for 31 provinces in China for the period 1995-2008 to examine the self-sufficiency of China's domestic cereal harvest. It aims to answer three questions: (1) Is the size of China's current grain stock adequate to buffer for seasonal crop failures of the same magnitude as past events? (2) Does producing a range of crops in one province reduce the risk of natural hazards causing production shocks? (3) Which regions are less likely to be affected by natural hazards and should therefore be set aside as agricultural land in order to meet future food self-sufficiency targets?

The results show that in a "theoretical worst-case scenario" China's cereal harvest may drop by 140 Mt. Therefore, their current grain stock of 120-200 Mt is sufficient to buffer China's cereal supplies against one year of production problems. Provinces with high crop diversity during 1995-2008 were less affected by floods and more affected by droughts. Food self-sufficiency was highest in moderately diverse provinces. In terms of those regions least affected by natural hazards, unsurprisingly droughts had higher impacts in the north, while floods and droughts had more equal impacts in the south. Droughts had increasing trends in two-thirds of the country.

Key Words

drought, flood, grain crops, land use, grain reserve

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1. Introduction

The global food price inflation that culminated in 2007-2008 gave numerous examples of how multi-faceted food insecurity is, both in its causes and effects. Causes ranged from (i) long-term institutional build-up, e.g. declining grain stocks and investments in agricultural research while the food demand increased, (ii) intermediate price fluctuations related to oil prices and grain trade pricing mechanisms, to (iii) short-term regional production failures, such as droughts in key wheat exporting countries (Abbott et al., 2008; FAO, 2008; Headey and Fan, 2008). This resulted in a tripling of food prices, an estimated 100 million people returning into poverty and hunger, and in actions from local food riots to national level protectionist measures, such as export bans (von Braun, 2009).

At first China was accused of contributing to the global food price inflation. It was argued that China's growth in population and purchase power over the recent decade had increased the demand for food (BBC News, 2008; Financial Express, 2009). Subsequent scientific analyses have pointed out that, although China supplies about one fifth of the global grain production, it trades very little in the three main staple crops rice, wheat and maize, and hence is largely self-sufficient (Dawe, 2009). However, although its contributions to the recent food crisis were exaggerated, China's grain demand is expected to increase for at least the next two decades through population increase, purchase power, animal feed and possibly bio-fuels. Moreover, combinations of similar characteristics to those causing the global food crisis can be found within China, e.g. deteriorated research into grain crops, controlled markets, and crop failures related to natural hazards (Huang et al., 2004; Liu and Diamond, 2005).

Food self-sufficiency has been a top priority for the Chinese government for decades. More recently, China has stated a clear policy that it intends to produce 90-95% of its own food, and set three targets for achieving this:

(1) To keep a *g*rain stock equal to 120-200 million metric tonnes (Mt) grain to buffer for at least three months (grain refers to rice, wheat, maize, soybean, tubers, and other cereals which are unspecified e.g. millet, sorghum, buckwheat) (State Council, 2008; Zhan, 2008). For comparison, the world cereal stock in 2010 is expected to reach 520 Mt (FAO, 2010) (here, cereal refers to rice, wheat, maize). Announcing the size of the grain stocks was believed to have had a calming effect on speculation on international and national markets (von Braun, 2009).

(2) To raise grain production to 500 Mt by 2010 and 540 Mt by 2020. This is equal to about 375 kg/capita/year in 2010. This would be done primarily through more effective land use, improved high-producing crop varieties and reducing post-harvest losses (State Council, 2008; Zhan, 2008). The trends over the past two decades show that production has been declining for rice and wheat which are the two primary staples for human consumption, while higher value crops such as maize and soybeans have been increasing slightly (Fig. 1a). It is worth noting that the size of the world's current grain stock is nearly the size of China's total rice production.

(3) To set aside 122 million hectares (Mha) for agricultural production by 2020. It is unclear what type of land is to be included in the 122 Mha: China's *total sown area* (including all arable land such as grain, oil crops, vegetables etc) has been hovering around 150 Mha for the last two decades, hence the target would already have been reached. In contrast, the *grain cultivated area* has declined over the last 15 years and was just about 100 Mha in 2008 (Fig. 1b). If the 122 Mha refers to the grain cultivated areas, as is assumed in this paper, the expansion is expected to come through land use intensification and in particular by merging small plots (State Council, 2008; Zhan, 2008). Recent farmland expansion has primarily taken place in northeast China as topography (Liu et al., 2010), climate and urbanisation are limiting further conversion in other parts of the country. Furthermore, the decline in grain acreage is partly offset by a yield increase between 1990 and 2008 (rice and maize yields increased by 1 t/ha (equal to 15 and 20% respectively), wheat yields by over 1.5 t/ha (50%), beans, tubers and other cereals by 0.5 t/ha (25, 20 and 20 %)). To produce 540 Mt grain on 122 Mha requires an average productivity of 3.7 t/ha, which has been surpassed for rice, maize and wheat (6.5, 5.5 and 4.75 t/ha in 2008). For an extensive review of China's agricultural policies see Chen(2009) and UN China (2008).

Given the size of China, 20% of the world's population, <7% of the world's cultivated land (Zhao et al., 2008), even small changes in supply and demand could have large global impacts if China had to look beyond its borders to restock its food stores. It is unknown to what extent 3 months of stocks (120-200 Mt), and 540 Mt on 122 Mha by 2020 are sufficient in case of an unexpected stress on crop production.

The aim of this paper is to look into China's food self sufficiency policy from a provincial viewpoint. Three specific questions that were asked were: (1) Is the size of China's current grain stock adequate to buffer for seasonal crop failures of the same magnitude as past events? (2) Does producing a range of crops in one province reduce the risk of natural hazards causing production shocks? (3) Which regions are less likely to be affected by natural hazards and should therefore be set aside agricultural land for future food self-sufficiency targets?

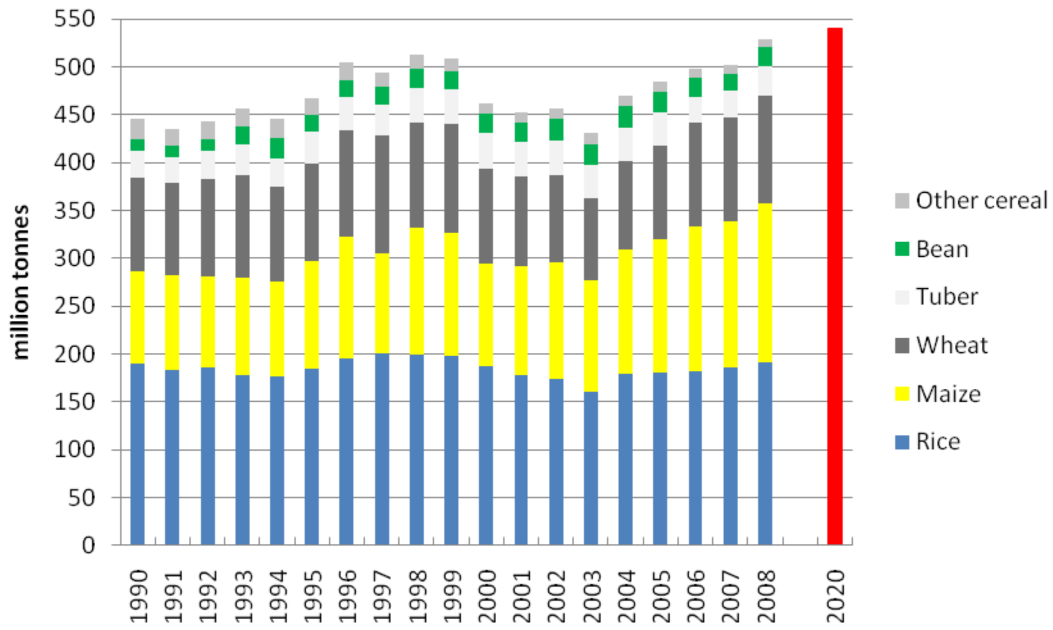

Figure 1a. Total production of grain crops and the share of the five main crops for China 1990-2008. The red bar indicates the food self-sufficiency target 540 million tonnes by 2020. Source: China Statistical Yearbook 1991-2009.

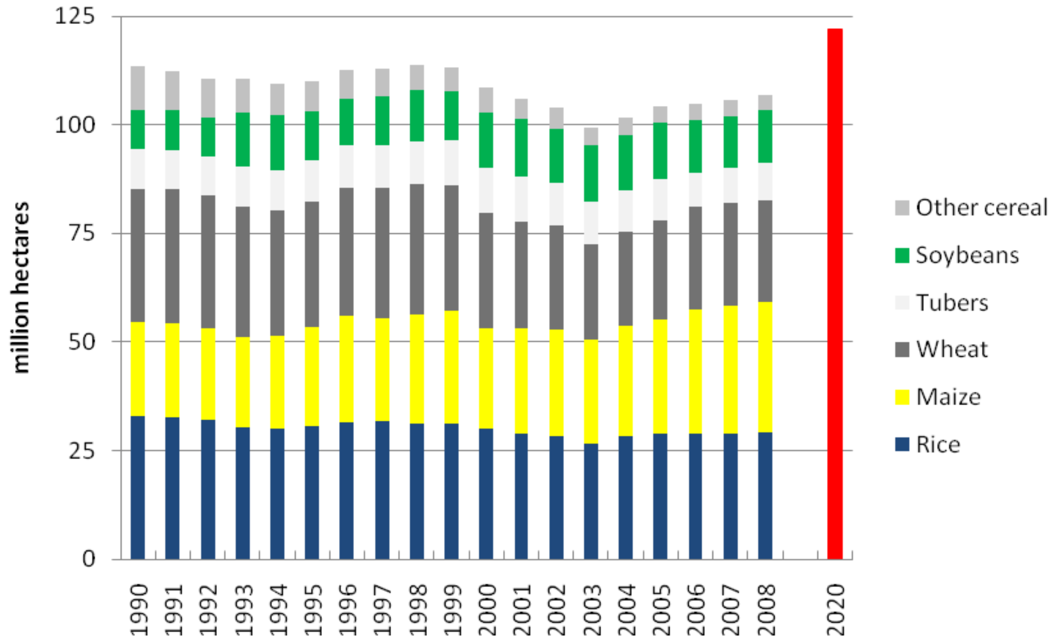

Figure 1b. Area cultivated with grain crops and the share of five main crops for China 1990-2008. The red bar indicates the 122 million hectare agricultural land target for food self-sufficiency by 2020. Source: China Statistical Yearbook 1991-2009.

2. Data & Methods

The publicly available data for China's agricultural production and natural hazards areas is restricted to statistical yearbook data for the period 1995-2008.

2.1 Data

Annual agricultural production and sown area for rice, wheat, maize, soybean, tubers, and other unspecified cereals (e.g. millet, sorghum, buckwheat) as well as areas affected and covered by floods and droughts natural hazards were obtained from China Statistical Yearbook 1996 to 2009 online database (www.stats.gov.cn) for 31 provinces for the period 1995-2008. Online data for 2002 is corrupt and has not been interpolated. At the national level, 2002 was an average year in terms of natural hazards. The natural hazards data is divided into covered and affected areas, which are defined in terms of economic losses. 'Covered area' denotes the sown area where more than 10 % of yields are reduced by the natural disaster and 'affected area' is where more than 30 % of yields are reduced by natural disaster (CIESIN and SEDAC, 1997-2009). Areas exposed to hail and frost were excluded as these constituted a minor share of the total area.

The future rainfall scenario was illustrated with the Chinese Global Circulation Model FGOALS Scenario SRA1B for the time slice 2040-69 (LASG, 2010). The scenario is the estimated change in the rate of change, calculated as the annual precipitation for 2040-69 divided by the baseline 1961-90 (http://www.ipcc-data.org/ddc_change_field.html). This was chosen as an example, as there is a general agreement among the GCM outputs that East Asia is getting wetter (IPCC, 2007).

Caveats to the data. Chinese official data, including agricultural and population statistics, are commonly perceived to be inaccurate. However, data quality has improved since mid-1990s, for example, through land area estimations via satellites (Gale, 2008; Liu et al., 2005; Seto et al., 2000). China Statistical Yearbook publishes 'sown area' where FAOSTAT uses 'harvested area'. Thus, in practice there should be a difference. However, both sources give equal areas for rice, wheat and maize, while China's (sown) figures for soybean are on average three million hectares higher than those of FAOSTAT (harvested). Natural hazards data is not crop-specific and is therefore analysed separately from the crop-specific harvest failures.

2.2 Methods and Indicators

With the above data, the following indicators were derived for analysing the adequacy of the grain stock, the influence of crop diversity on natural hazard-impacts, and the location of less natural hazards-prone future farmland.

Actual worst shortfall: The 'actual worst' shortfall was the year when most number of provinces had negative anomalies, where harvest anomalies were calculated as the actual value subtracted from the mean value for the period 1995-2008.

Theoretical worst shortfall: To envision the magnitude of a large-scale crop failure and its potential effects on the buffering capacity of China's grain stock, we assume that the worst crop failures happened simultaneously for all crops in each province in the same year. Hence, the 'theoretical worst' harvest anomaly was created by aggregating the largest negative harvest anomalies from all provinces (i.e. their record crop failure between 1995 and 2008) to give the 'theoretical worst' scenario at a country-level. In addition, the second theoretical worst harvests were also added to establish the severity of two consecutive theoretical worst years.

Crop diversity: A nominal value for a province's diversity in grain crops was set as the number of grain crops that occupied ≥10% of the total sown area.

Food self-sufficiency: To correspond to the national target, food self-sufficiency is assumed to be 375 kg cereal per person per year. Harvest anomalies therefore refer to total production rather than productivity (tonnes per hectare), as productivity would hide the total amount of grain available at the national level.

Impact of natural hazard: The ratio 'area covered' by drought or flood to the 'total sown area' was considered as an impact. The area covered is defined as an area with ≥10% harvest loss, hence crop failures <10% count as normal variability. There was little difference if impacts were calculated as the area affected divided by the total cultivated area, other than in the size of the ratio. Because natural hazards data is not crop-specific, all farmland was taken into account.

Sensitivity to natural hazard: The trend of the ratio 'area affected' to 'area covered' by the natural hazard was used to illustrate sensitivity. The affected area is defined as an area with ≥30% harvest loss. This ratio enabled a comparison of severity of the impact between floods and droughts and between provinces. The trend was projected to indicate future areas of concern, e.g. provinces with increasing sensitivity to droughts overlap with areas that the GCM-output show as drier.

3. Results

3.1 The Buffer

The actual worst crop failures between 1995 and 2008 are shown in Table 1. Overall, the annual total shortfalls for grain (right column) ranged between 13- 64 Mt. The year 2003 had the largest loss in volume and the greatest number of shortfalls: 122 observations (on average 66% of the data), including negative anomalies for all 30 wheat growing provinces and for 28 of 30 rice growing provinces. The largest crop failures for maize were recorded in 1997, for beans and tubers in 2007 and for other grains in 2008.

<Table 1 around here>

<Table 2 around here>

The theoretical worst crop failures are shown in Table 2. Assuming that the record low shortfalls had happened in the same year for all provinces and all crops would have generated a 143 Mt shortfall. Despite that wheat and maize covered similar-sized areas (on average 27 and 24 Mha respectively), wheat shortfalls were three-quarters of those of maize. The theoretical second worst crop failure indicated a 105 Mt shortfall.

3.2 Crop Diversity

The range of grain crops by province (table 2, right column) and in relation to natural hazards, total theoretical worst shortfall (table 2, second column from the right) and average food self-sufficiency are summarised in Table 3. Two key grain crops were the most common land use (16 of 31 provinces) while five provinces specialised in one crop, and ten provinces diversified with three or four crops. Flood impacts were most severe with specialisation and least severe in provinces with diversity (3-4 crops). In contrast, drought impacts were most severe with diversity and least severe with specialisation. In terms of natural hazards, specialised provinces had the smallest theoretical worst shortfalls while those with three crops had the worst shortfalls. More importantly, only one province with high diversity four grain crops was food self- sufficient, while for those with three grain crops the majority of provinces were self- sufficient and met the 375 kg grain per person per year.

The eight largest total theoretical shortfalls occurred in food self-sufficient provinces with two or three key grain crops, among these were three provinces in northeast (Fig. 2). More specifically, less than half of China's provinces were 'food self-sufficient' (i.e. produced on average 375 kg grain per capita) between 2001 and 2008 (13 of 31 provinces). This was no major change compared with 1995-2001: the number of food self-sufficient provinces declined by one province while the grain production per capita decreased (increased) in 17(14) provinces for the period 2002-2008.

<Table 3: Crop diversity & other results >

< Figure 2: food self-sufficient provinces >

3.3 Natural Hazard Impacts

The two previous sections inferred that provinces with one and two key crops were mostly located in the extreme west or east (coastal region), while those with three and four grain crops were in the central parts. In fact, most of the food self sufficient provinces appeared in a belt from Sichuan in southeast across the North China Plain to Heilongjiang in northeast (Fig. 2). This area largely coincides with the provinces with largest sown areas in Figure 3. The bar graphs further indicate that this region experienced smaller drought impacts (shares of the total sown area ‘covered’) compared to northern provinces, and smaller flood impacts compared to southern provinces. In contrast to the north, the southern provinces were more equally impacted by floods and droughts.

In terms of crop diversity, Table 2 shows that provinces with three major grain crops had the smallest flood impacts and provinces with one crop had the smallest drought impacts. In terms of food self-sufficiency, there was a general trend for higher average levels of food self-sufficiency and increasing impacts of drought (R^2=0.18, n=31), and similar trend for floods, except for the three food self-sufficient and less flood-prone provinces in northeast (R^2=0.13, n=28 and R^2=0.05, n=31 excluding and including the northeast respectively).

Figure 4 shows the sensitivity trends (ratio of areas ‘affected’ to ‘covered’ by natural hazards) between 1995 and 2008 (bar graphs), overlaying an example scenario of annual rainfall changes for the 2050s (grids). Drought sensitivity was high in areas projected to become drier, in particular the southern parts of North China Plain and east-central China. In contrast, flood sensitivity increased in only one of the provinces with expected increases in rainfall in the northeast (Liaoning). Both areas with increasing sensitivity to natural hazards and exposure to rainfall changes are thus located in current key grain regions.

< Figure 3 around here: impact>

<Figure 4 around here: scenario>

4. Discussion

4.1 The Buffer

China’s alleged grain reserve, 120-200 Mt, is at least twice the size of the actual worst crop failure in a year (-64 Mt) or about the same size if all provinces suffered the ‘theoretical’ worst shortfall for all crops in the same year (-143 Mt). A reserve of this quantity may not be under stress until after two consecutive years of the largest and second largest shortfall for all crops (-248 Mt). This implies that natural hazards had little impact on the national food self-sufficiency.

National grain supply is a limited indicator of grain self-sufficiency, as it does not guarantee physical or economic access to food at the individual/household-level, nor does grain alone meet all nutritional requirements (Devereux, 2009; Ericksen, 2008; Maxwell et al., 2009). However, low prices on staples may cause micronutrient malnutrition if vegetables and proteins take over household expenditures so that poor families compensate by eating more grain (Klotz et al., 2008). Moreover, scepticism has been raised about the true size, quality and management of China’s grain reserves in association with the national grain reserve audits in 2009 (agrimoney.com, 2010; People's Daily, 2009). Furthermore, new speculations have already started after China's sale of domestic grain reserves followed by an "unexpected" purchase of maize from the U.S. in 2010 (Javier, 2010). Sizing a grain reserve is non-trivial, however. Just as minimal stocks may trigger speculation, food-policy experts warn that excessive grain reserves are expensive to keep, risk that food gets damaged, and may equally upset domestic and international markets (von Braun, 2009). Although there are policies in place to desensitise food self-sufficiency to economic changes, the consequences of these interventions may be more difficult to forecast than seasonal weather.

Against this backdrop, transparent grain reserves of 120 Mt are adequate for ensuring national food self-sufficiency in the event of a domestic natural hazard. Who has access to that food depends largely on prices, *which* grains are affected and how quickly the market responds to those particular and other, compensatory, crops.

4.2 Crop Diversity

This study suggests that floods and droughts have the opposite impacts on low and high crop diversity. The provinces with high flood impacts and specialising in one grain crop are situated along the south coast, exposed to a monsoon climate – which explains the low exposure to droughts - and have high urbanisation rates. In general many of the provinces with high grain crop diversity were located in the north.

The low crop diversity in the south results may be confounded by two facts: rather than promoting grain crops, some of those grain-specialised provinces, e.g. Hunan and Guangdong, utilise their comparative advantages to grow cash crops (e.g. oil seeds, horticulture) or to produce meat. In contrast, the northern farmers diversify with staple crops as a response to the prevailing climate: there are fewer cash crop options and a lack of irrigation that has generated a domestic virtual water debt (Khan et al., 2009; Ma et al., 2006). Moreover, in contrast to floods, droughts occur in all seasons and may delay subsequent planting. Hence, slower crop growth can be both a cause and effect of drought impacts. Furthermore, specialisation generally helps farm enterprises making profits, which directly (for state-owned farms) or indirectly mobilise national grain reserves. In contrast, diversification helps small-holders whose primary objective is household-level subsistence.

Provincial data may give a limited account of the role of grain crops/cultivars for food self-sufficiency. Crops grown for subsistence are not included in statistics and/or disappear in provincial total production totals. For example, locally-adapted grains are hidden under "other crops" and can include sorghum and millet in semi-arid provinces or barley in Tibet. Household-level case studies confirm that following the transition to a market economy, farmers choose crops primarily in response to economic changes, and adapt their management approaches in response to weather, e.g. by using greenhouses, plastic mulching etc (Hageback et al., 2005). Farmers' moves towards using improved crop varieties is fuelled by the fact that current grain yields meet only 20-40% of their potential capacity (Yan et al., 2006). However, while crop improvements and technological inefficiencies may be overcome, soil quality could limit productivity on most farmland. Yan *et al* (2006) report that 70-80% of the cultivated land in China is nutrient deficient while 10% is polluted, partly from over-fertilisation. More recent data report that acidification from over-fertilisation is "widely occurring" (Guo et al., 2010). This suggests that the increasing sensitivity trends in this study (Fig. 4) are underestimated.

In contrast, intercropping grain with other crops can increase yields by up to 87% (Li et al., 2009). Intercropping reduces the risk of delaying planting after adverse weather. Such practises may give more stable farm output and reduce environmental risks associated with intensive mono-cropping, such as over-pumping ground-water and soil-exhaustion due to over-use of fertiliser and pesticides (Khan et al., 2009; Zhang et al., 2007a; Zhao et al., 2008). Moreover, future food self-sufficiency will need mono- and multicultures to co-exist (Fedoroff et al., 2010). There is already a repertoire of opportunities to increase yields by water-harvesting management (Wang et al., 2009; Zhang et al., 2007b), integrated rice-fish cultivation (Fernando and Halwart, 2000) and genotypic adaptation (Challinor et al., 2009), e.g. potatoes due to their potential in climatically-restricted regions and in between rotations (Keane, 2010). Peri-urban agriculture with more efficient use of inputs (Zhang et al., 2007a) also offers an important opportunity.

4.3 Geography of Natural Hazards and Future Farmland

This study showed that China's current food self-sufficiency largely depended on three provinces in the northeast managing to produce significantly more than the provincial food self-sufficiency requirements (Fig. 2). The northeast region has become vital for food self-sufficiency because of: (i) a favourable climate, (ii) land availability/less urbanisation, and (iii) a high frequency of state farms. However, there are some concerns with depending too heavily on this region when setting aside the 122 Mha farmland noted by government targets. First, it presumes that the central provinces, which are on the border of self-sufficiency, increase their production per capita to keep at pace with population growth/demand. Although Jilin, Heilongjiang, Inner Mongolia and Liaoning each produced more food than required for its population (Fig. 2), these four provinces constituted only one quarter of China's total grain area (24 Mha) and have little extra land to expand on to (total cultivated area 28 Mha in 2008). Although some future climate scenarios may look appealing for agriculture in the northeast, it is important to bear in mind that these provinces also accounted for one third of China's 'theoretical worst shortfall' (Table 2). On the positive side, rainfall is projected to increase and drought impacts have better chances of being prevented by water-harvesting methods and early warning systems than do floods. While torrents can be locally devastating, the flooding across 26 provinces in 2010 is projected to 'only' reduce rice production by 10% (Rong, 2010).

Second, exaggerating one region's strengths may deter adaptive capacity from other places. Table 3 highlighted two extremes of food insecurity: remote rural regions that depend on small-scale unproductive agriculture (due to climate, topography etc) versus densely populated urban regions which depend on food purchases. Indeed, sensitivity to droughts and floods increased in four provinces, both in the semi-arid (Gansu) and humid central regions (Anhui, Jiangsu and Zhejiang) (Fig. 4), thus highlighting locations where agricultural adaptation may become particularly difficult. These contrasting examples are indicative of a broader issue related to poverty alleviation and access to food (Lu et al., 2009), namely a shift from traditional to peri-urban agriculture as land rents increase, from state controlled grains to less regulated cash crops and, as result, more dynamic local markets. In eastern China, peri-urban agriculture absorbs migrant labour (from remote (western) rural areas). Some argue that it competes with agricultural investments that may be better spent on the poorer countryside (van Veenhuizen and Danso, 2007), as it contributes to poorly integrated economic sectors locally and increasing developmental gaps nationally (Lu et al., 2009). Paradoxically, farms again provide household self-sufficiency, which validates the invisible value of having a small farm to return to for subsistence in times of crisis, something to which landless people do not have access (Morton, 2007). Studies show that there is potential for more exchange between rural and urban areas than simply labour flow eastwards and their remittance flow westwards, e.g. knowledge transfers brought by returning migrants (Murphy, 2000).

Third, land intensification processes in northeast are likely to further favour State farms. Grain cultivation seldom is the way to poverty alleviation and state farms' production may not outcompete small-scale and subsistence farmers, but may interfere with rural livelihoods in the form of land conversion and relocation of small-scale farmers. On the other hand, greater concentrations of larger farms allows the uptake of technological improvements to be faster and more efficient, including long-term adaptation to climate change (Yang et al., 2007) that could benefit small-holders too.

4.4 Future Food Self-Sufficiency

The ability to meet future grain targets may be restricted directly and indirectly by socio-economic and climate changes. China's most critical period in terms of food self-sufficiency is from the present time up to the expected population peak in the 2030s. One study projects that China's grain demand will increase from 648 Mt by 2020 to 700 Mt by 2050 while it would be able to supply 526 Mt by 2020 and 656 Mt by 2050, therefore due to the expected population peak self-sufficiency levels could increase from 365 in 2020 to 468 kg/capita by 2050 (Zhao et al., 2008). Another study, accounting for soil degradation and urbanisation but not climate change, projects per capita production between 240 and 340 kg by 2050 (Ye and Van Ranst, 2009), i.e. well below self-sufficiency levels. Socio-economic changes may affect rural access to capital, land and labour that leads to socioeconomic vulnerability to drought (Simelton et al., 2009). As urbanisation rates are projected to increase from 40% in 2000 to 80% in 2050 (Ye and Van Ranst, 2009), economic access to food will become an increasingly central aspect of China's food self-sufficiency policies. Although this study focused on floods and droughts, climate change is associated with more extreme weather events and warmer temperatures (Battisti and Naylor, 2008), increasing ground-level ozone production on near-urban farmland (Chameides, 1999) and spread of pest and crop disease (Gregory et al., 2009). Such factors could play out the uncertain benefits of atmospheric CO_2-concentrations (Chavas et al., 2009; Reilly et al., 2007) and make future theoretical worst case scenarios worse. When accounting for climate change impacts, research shows that crops such as potato and groundnut may be better adapted than rice, wheat or maize (Lobell et al., 2008), thus future food reserves may look very different from the way they look now.

Moreover, in terms of the 122 Mha expansion of farmland, land and land quality may be another limiting factor. One estimate suggests that 1.36 ha of cultivated land is lost for every CNY1000 increase in GDP (Zhao et al., 2008 p. 900). Two pathways for sustainable agriculture in China were identified nearly two decades ago and later absorbed into climate mitigation policies (ACCA, 1994; NRDC, 2007). Agricultural intensification will make the bulk of China's food self-sufficiency and primarily involves merging fields and increasing yields. This requires investments (or subsidies) that apply to bigger farms and primarily benefit consumers. Assuming that current trends in sensitivity to natural hazards remain, in particular to droughts, the number of grain self-sufficient provinces may decline further (Fig. 3 & 4) and concentrate the domestic food self-sufficiency to even fewer provinces in the northeast region. It therefore seems critical to also sustain North China Plain's land resources as part of the 122 Mha. The other pathway, conservation agriculture, applies to fragile, remote or land-limited areas. Its main contribution is to local development rather than national food self-sufficiency. One alternative to cultivating fragile environments is to pay farmers for providing ecosystem services, such as storing soil carbon (Pimentel, 2006). For example, some agro-ecosystems, such as the Loess Plateau slopes, have such low productivity that taking some soils out of use would hardly be noticeable at the provincial/national level production (Xu et al., 2006). Both the intensification and conservation examples illustrate that food self-sufficiency could be strengthened simply by allocating money invested in agriculture more effectively, i.e. from fertiliser to water and seeds.

Land intensification and conservation are, among other things, intended to make the bulk of the grain food self-sufficiency (90-95%) while the remainder (5-10%) is expected to be supplied from abroad. China has become an overall net food exporter over the past 20 years (Ng and Aksoy, 2008). During the 2000s China's imports of rice, wheat and maize have been below 5% of the total world imports and exports ranged between 1-10%; while China's share of the world supply ranged between 17-20% (wheat, maize) up to 40% (rice) (USDA, 2010). Although grain makes up a small share of China's trade, cash crops (in particular oil crops), grain for feed and biofuel (in particular maize) imports are expected to increase into the future, primarily to meet urban food and energy demands (UN China, 2008). With regards to future climate change many of the world's grain producing areas may be facing severe yield declines (Lobell et al., 2008), which will bring new trade patterns. One such pattern is acquisitions of agricultural land abroad. These agreements have expanded after the food price inflation in 2007-08 2009 (UNCCD, 2010) and a recent estimate suggest that China acquired at least 6 Mha farmland abroad between 2006 and 2009 (UNCCD, 2010). Although not all that land is used for grain crops, it already makes a staggering 5% of the 122 Mha. This kind of long-term trade with farmland is expected to continue into a foreseeable future (Kugelman and Levenstein, 2009; von Braun and Meinzen-Dick, 2009).

5. Conclusions

China's current grain buffer is adequate to cover for unexpected crop failures related to natural hazards. The actual worst grain crop failures (-63 Mt) and the theoretical worst crop failures (-143 Mt) would have been covered by a grain reserve of 120-200 Mt. Perhaps more critical than the volume, is a transparent grain reserve system.

Grain diversity is associated with climatic exposure and urbanisation levels. Flood impacts were highest in provinces specialised in one grain crop, drought impacts were highest in provinces that diversified in three-four crops. In addition, the group with three main grain crops had the highest food production per capita and largest share of grain self-sufficient provinces.

Future food self-sufficiency is likely to become more concentrated in the northeast and parts of the North China Plain, i.e. increasing the dependency on a smaller number of provinces. This is based on the location of current largest areas of agricultural land and highest food self-sufficiency levels, that sensitivity to drought hazards increased and to flood hazards decreased in most provinces, and that rainfall is projected to increase in current drought-sensitive/flood-insensitive regions. The appropriateness of 122 Mha and their locations depend on productivity and exposure to environmental and economic changes.

The main means to achieve national level grain self-sufficiency are domestic land use intensification (90-95% of food supply), international trade and (increasingly) land acquisition (5-10%). Niche and conservation agriculture can enhance local food self-sufficiency and poverty alleviation, and play important roles for experiments with multipurpose land uses and compensation for ecosystem services.

Table 1. Actual worst shortfall. Accumulated negative harvest anomalies (million tonnes, Mt) and number of provinces with negative anomalies (n). for 31 provinces in China over the period 1995 to 2008. Anomalies are based on the mean for 1995 to 2008. Note that only provinces with negative anomalies (shortfalls) for that year are included.

	Rice		Wheat		Maize		Beans		Tuber		Other cereal		Total grain	
Year	(Mt)	N	(Mt)	n	(Mt)	n	(Mt)	n	(Mt)	n	(Mt)	n	(Mt)	n
1995	-11.35	14	-9.52	8	-17.14	20	-2.94	18	-3.71	18	-0.41	5	-45.07	83
1996	-6.67	10	-5.80	5	-7.39	18	-2.95	17	-2.77	14	-0.41	4	-25.99	68
1997	-3.23	7	-0.86	1	-26.66	24	-1.84	17	-3.97	19	-0.35	6	-36.91	74
1998	-4.45	8	-7.18	3	-4.27	18	-1.86	12	-2.34	14	-0.64	7	-20.75	62
1999	-1.97	7	-1.85	2	-5.34	15	-2.00	13	-1.78	15	-0.48	13	-13.43	65
2000	-3.80	10	-6.69	12	-25.52	21	-1.62	12	-0.86	10	-1.66	12	-40.15	77
2001	-10.01	18	-10.91	19	-17.32	21	-0.83	9	-1.21	11	-1.60	18	-41.88	96
2002	*nd*		*nd*		*nd*		*nd*		*nd*		*nd*		*nd*	
2003	-26.82	28	-18.01	30	-14.96	22	-0.98	9	-1.51	13	-1.41	20	-63.68	122
2004	-9.86	22	-12.79	28	-5.70	17	-0.42	8	-1.11	15	-2.33	24	-32.23	114
2005	-9.31	17	-8.26	28	-1.90	6	-1.08	13	-2.29	16	-1.97	25	-24.81	105
2006	-10.53	18	-4.98	27	-1.25	8	-1.00	14	-2.42	18	-2.34	24	-22.51	109
2007	-10.92	19	-6.18	23	-0.53	8	-3.45	22	-7.60	21	-3.42	24	-32.09	117
2008	-9.38	18	-4.97	23	-0.34	4	-1.87	23	-6.84	22	-4.23	25	-27.63	115

Table 2. Theoretical worst shortfall. Record negative harvest anomaly (Mt) based on the mean for 1995-2008. Each column gives the theoretical worst shortfall by crop, each row the theoretical worst crop failure by province for any of the years between 1995 and 2008. Note that only years with negative anomalies (shortfalls) are included. Crop diversity index indicates the number of grain crops occupying ≥10% of the total sown area.

Region	Rice	Wheat	Maize	Beans	Tubers	Other Cereal	Total by province	CDI
Anhui	-3.08	-2.41	-0.46	-0.44	-1.10	-0.34	-7.83	2
Beijing	-0.06	-0.34	-0.46	-0.01	-0.01	-0.01	-0.89	2
Chongqing	-1.21	-0.32	-0.31	-0.13	-0.50	-0.08	-2.55	4
Fujian	-1.05	-0.07	-0.03	-0.09	-0.45	-0.04	-1.72	2
Gansu	-0.01	-0.58	-0.97	-0.28	-0.77	-0.72	-3.34	4
Guangdong	-3.01	-0.03	-0.35	-0.05	-0.44	-0.03	-3.91	1
Guangxi	-0.96	-0.02	-0.29	-0.15	-0.06	-0.01	-1.48	1
Guizhou	-0.16	-0.41	-0.81	-0.06	-0.48	-0.05	-1.98	4
Hainan	-0.38	0.00	-0.02	-0.02	-0.07	-0.01	-0.48	2
Hebei	-0.26	-1.58	-1.79	-0.22	-0.33	-0.44	-4.61	2
Heilongjiang	-5.40	-1.17	-3.72	-1.32	-0.36	-0.27	-12.24	3
Henan	-1.43	-6.50	-4.07	-0.32	-0.97	-0.27	-13.57	2
Hubei	-2.20	-1.23	-0.39	-0.17	-0.68	-0.05	-4.72	2
Hunan	-2.88	-0.15	-0.67	-0.18	-0.38	-0.04	-4.29	1
Inner Mongolia	-9.92	-4.11	-3.67	-0.56	-0.71	-0.21	-19.18	4
Jiangsu	-3.81	-2.43	-0.53	-0.12	-0.35	-0.22	-7.47	2
Jiangxi	-2.52	-0.04	-0.02	-0.07	-0.10	-0.01	-2.76	1
Jilin	-1.15	-0.07	-6.77	-0.47	-0.20	-0.25	-8.91	3
Liaoning	-1.30	-0.22	-4.27	-0.12	-0.12	-0.48	-6.52	2
Ningxia	-0.23	-0.16	-0.46	-0.05	-0.15	-0.12	-1.16	3
Qinghai	0.00	-0.17	-0.01	-0.04	-0.08	-0.07	-0.37	2
Shaanxi	-0.23	-0.64	-1.53	-0.16	-0.39	-0.14	-3.09	2
Shandong	-0.31	-3.37	-4.71	-0.43	-0.88	-0.22	-9.92	2
Shanghai	-0.37	-0.12	-0.01	-0.01	0.00	-0.05	-0.58	2
Shanxi	-0.02	-0.56	-1.92	-0.10	-0.26	-0.72	-3.57	4
Sichuan	-2.47	-0.88	-1.28	-0.26	-0.72	-0.39	-6.00	4
Tianjin	-0.17	-0.20	-0.29	-0.03	0.00	-0.04	-0.73	2
Tibet	0.00	-0.03	0.00	-0.02	-0.01	-0.18	-0.23	2
Xinjiang	-0.13	-0.56	-0.84	-0.11	-0.06	-0.08	-1.79	2
Yunnan	-0.74	-0.46	-0.96	-0.37	-0.60	-0.46	-3.58	3
Zhejiang	-2.55	-0.22	-0.08	-0.11	-0.43	-0.15	-3.54	1
Total	-48.01	-29.07	-41.68	-6.49	-11.66	-6.12	-143.02	

Table 3. Crop diversity in relation to natural hazards impact, crop failure, food self-sufficiency and urbanisation

Crop diversity[1] (n provinces)	Flood impact Area covered/ tot sown (%) (avg)	Drought impact Area covered/ tot sown (%) (avg)	Theoretical worst crop failure [2] (-Mt) (avg)	Grain production (kg/capita) (average)	Food self-sufficient[3] provinces	Urban population (% in all provinces) (% in food self sufficient provinces)[4]
1 (5)	6-13 (9)	5-10 (8)	4-2 (3)	202-416 (315)	2	40-65 (40)
2 (16)	2-16 (6)	0-33 (15)	14-0 (4)	99-454 (314)	6	20-90 (35-60)
3 (4)	3- 6 (5)	12-34 (24)	20-0 (6)	330-850 (618)	3	30-60 (45-60)
4 (6)	4-10 (6)	7-38 (24)	7-0 (6)	290-632 (381)	1	30-60 (50)

Source: China Statistical Yearbook 1996-2009

[1]Grain crop occupying on average >10% of total sown area.
[2]Second column from right in Table 2.
[3]Province producing > 375 kg/grain/capita/year
[4]Urban population in 2008.

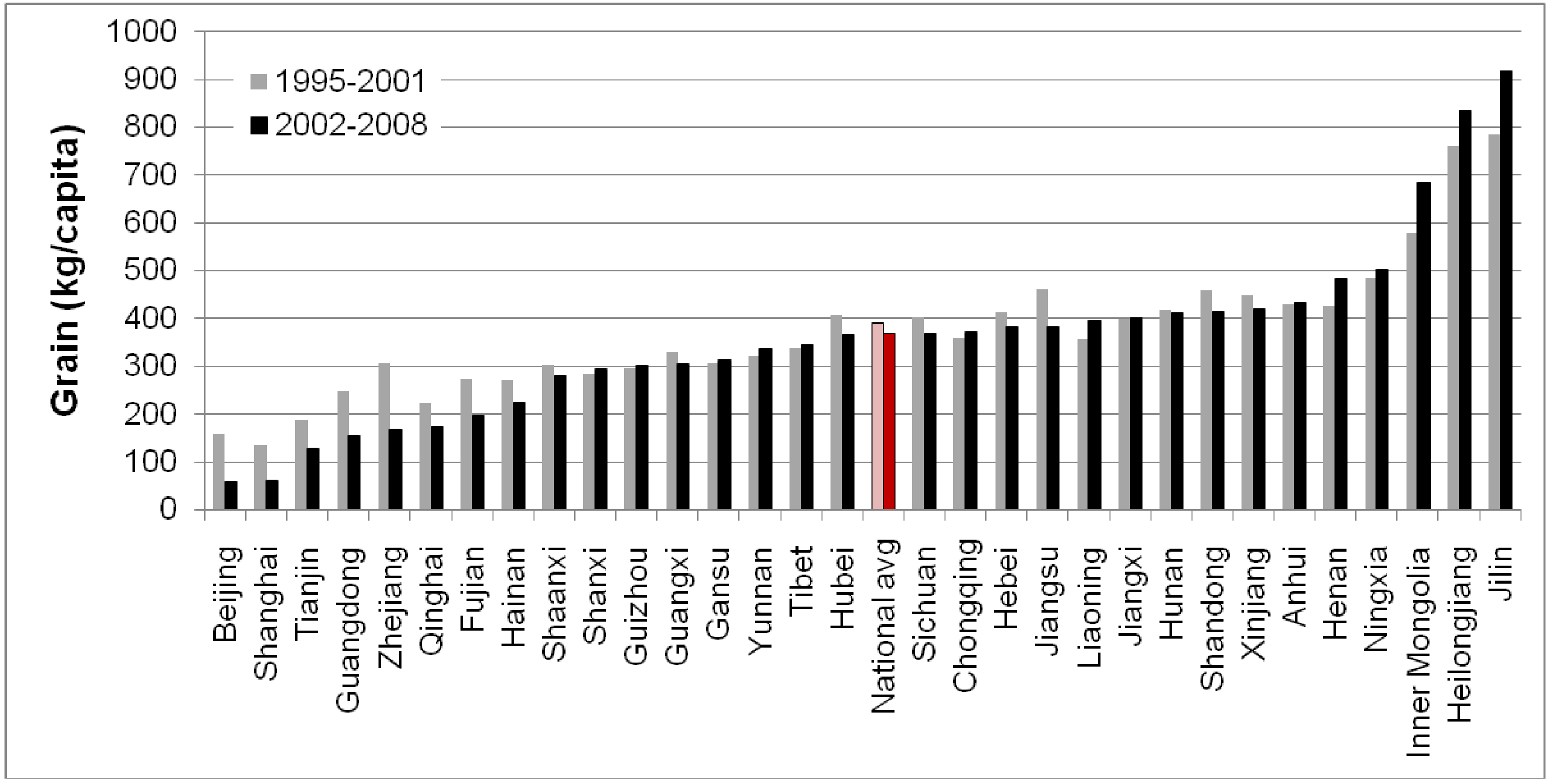

Figure 2. Food self-sufficiency, average grain production per capita for 1995-2001 (grey bars) and 2002-2008 (black bars). National average is shown as red bars with black contour lines for respective period. The minimum requirement for self-sufficiency in this study is 375 kg/capita/year.

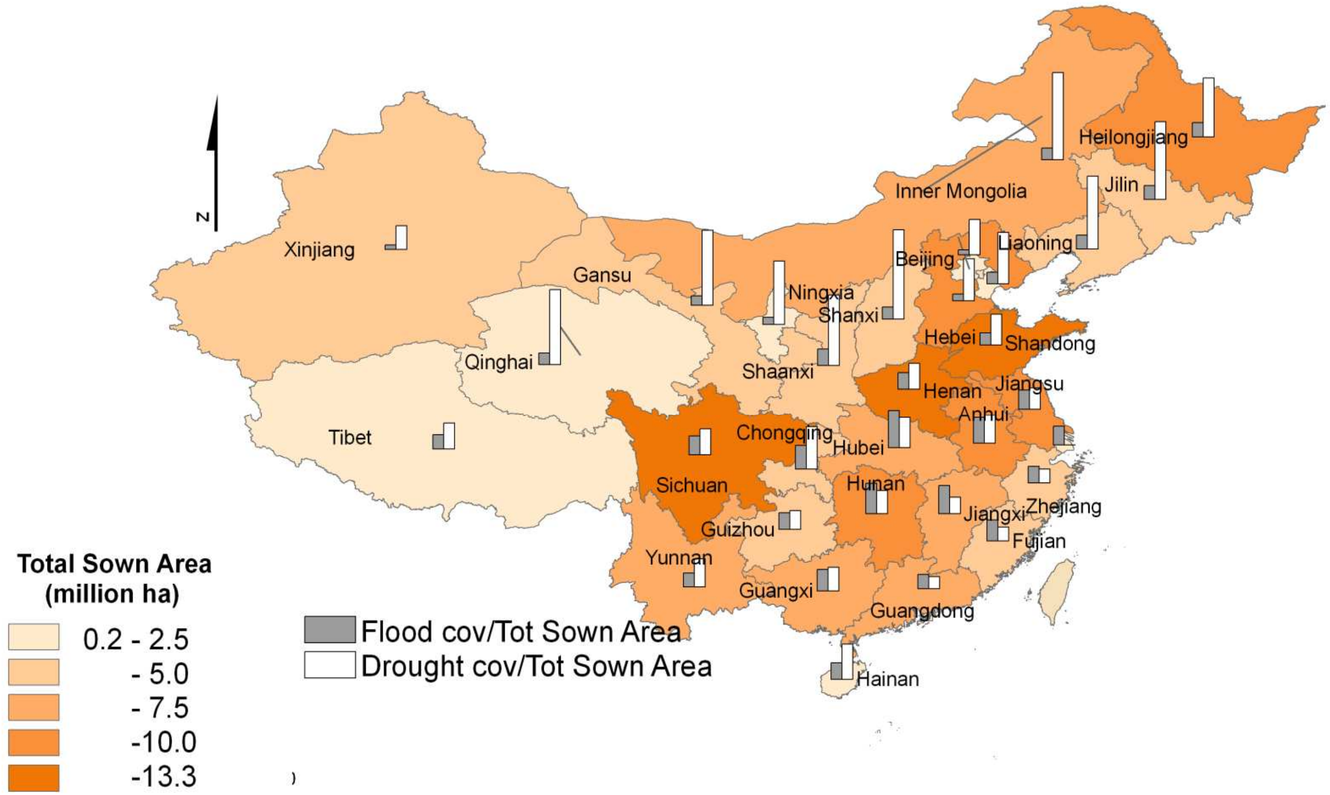

Figure 3. Average total sown area (million hectare) for the period 1995-2008 and natural hazard impacts. The bar graphs show the average area covered by flood (grey) and drought (white) as share of average total sown area. For scale, the bar values range between 2 and 16 % for flood and 0 to 38% for drought. The distance as-the-crow-flies between west Xinjiang and east Heilongjiang is about 4900 km. Source: China Statistical Bureau 1996-2009.

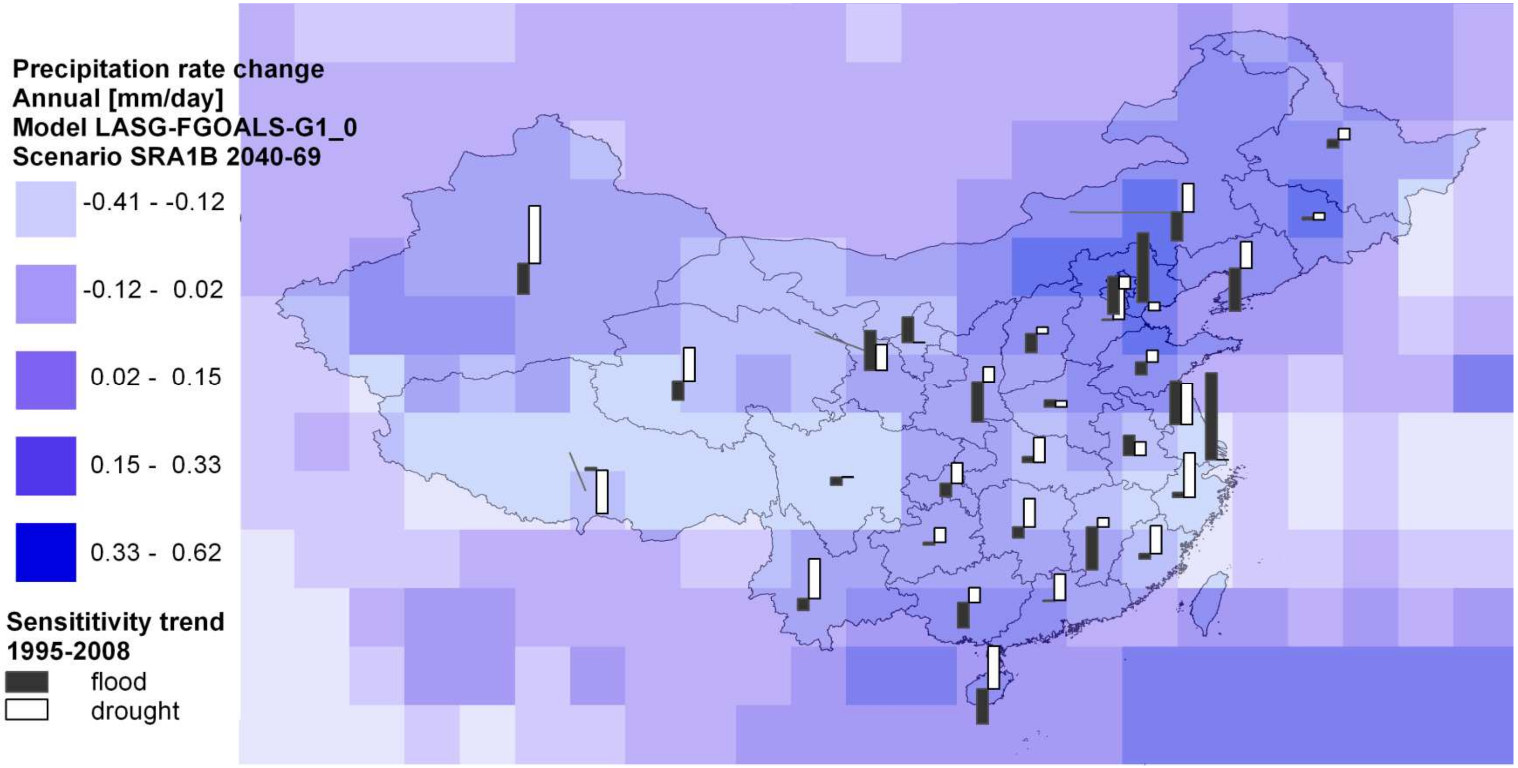

Figure 4. Historical trends in sensitivity to natural hazards (1995-2008), i.e. the ratio in area affected to area covered by flood (grey) and drought (white), overlaying future exposure to change in annual precipitation rate, i.e. precipitation change 2040-2069 divided by the baseline period 1961-1990 (LASG, 2010).

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