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ADAPTIVE CAPACITY TO CLIMATE CHANGE IN THE AGRICULTURE OF NORTHEASTERN CHINA

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ABSTRACT: Socio-economic indicators are selected to examine the adaptive capacity of Northeastern China to the impacts of climate change on agriculture. The approach is focused directly on the underlying determinants of adaptive capacity. The analytic hierarchy process (AHP) method is used to prioritize indicators to assess the potential contributions of various aspects to the systems coping capacities. Indicators are compared and analyzed. Web-mapping technology is introduced to visualize and disseminate the results.

Keywords: climate change, adaptation, indicators

1. Introduction

Climate change will result in a set of diverse and location specific impacts on agricultural production. A growing literature suggests that while climate mitigation strategies are necessary, that alone is unlikely to be sufficient. As the impact studies have shown, climate change from previous emissions of greenhouse gases will have to be confronted by all countries. Therefore, pursuing a complementary strategy of enabling the agriculture sector to adapt to climate change and negate many of the expected adverse impacts is equally, if not more, urgent (Adger and Kelly, 1999; Burton et al., 2002). A host of recent impact studies show that reducing vulnerability to climate change by strengthening the adaptive capacity of the agriculture sector can reap substantial benefits (IPCC, 2001). The issue of how to make the agricultural sector more resilient to expected climate change has become extremely relevant to policy makers in the developing countries and international donor agencies (Adger et al., 2003).

Given the range of current vulnerability and diversity of expected impacts, there is no single formula that can be followed. Instead, increasing adaptive capacity of the agriculture sector will require a host of complementary measures. The evidence suggests that it is necessary to overcome various factors that contribute to vulnerability regardless of the temporal dimension of climate change. In particular, low per capita income, high dependency on subsistence agriculture and natural resources, weak governmental and institutional capacity, prevalence of preventable and non-preventable diseases, high incidence of armed conflict, and dependence on aid have been identified as issues that make economic development and growth challenging (Desanker, 2002; Adger et al., 2003; Klein and Smith, 2003). Human communities have a huge capacity for coping with climate change. Adaptive capacity at the moment relies on information and social capital.

Vulnerability assessment is a key aspect of anchoring assessments of climate change impacts to present development planning. Methods of vulnerability assessment have been developed over the past several decades in natural hazards, food security, poverty analysis, sustainable livelihoods and related fields. These approaches - each with their own nuances - provide a core set of best practices for use in studies of climate change vulnerability and adaptation (Chambers, 1989; Bohle and Watts, 1993; Burton et al., 1993; Lin, 1996; Downing et al., 1997; Adger and Kelly, 1999; Downing et al., 2001).

Changes in the mean conditions that define environments can actually be experienced most noticeably through changes in the nature and/or frequency of variable conditions that materialize across short time scales. Adaptation necessarily involves reaction to this sort of variability (Downing et al., 2001; Yohe and Tol, 2002).

Many definitions of adaptive capacity exist (IPCC, 2001; Burton et al., 2002; Adger et al., 2003 Dolan, et al., 2001); broadly speaking it may be described as the potential or capability of a system to adjust, via changes in its characteristics or behaviour, so as to cope better with existing climate variability, or with changes in variability and mean climatic conditions. The realization of adaptive capacity occurs as adaptation serves to enhance a system's coping capacity and increase its coping range, and therefore decrease its vulnerability, with respect to particular type of climate hazard. Having adaptive capacity depends on the resources available for adaptation, the ability of those who need to adapt to deploy these resources effectively, and their willingness to do so. The resources that contribute to a human system's adaptive capacity include natural resources, financial capital, human capital, knowledge of risk, appropriate social institutions for managing risks, and appropriate technology (Bohle and Watts, 1993; Jones, 2001; Brooks and Adger, 2003).

While social determinants of adaptive capacity are difficult to observe and measure, some aspects of adaptive capacity, including physical infrastructure, resources and the distribution of those resources, may be assessed relatively easily both at national scales and at lower or higher levels of aggregation. A number of sets of national-level indicators developed within the UN system are used to build up a picture of national performance or status in areas as diverse as human health and economic trade (for example, data assembled by the World Health Organization, the World Bank, the United Nations' Development Programme, and others). Some proxies for generic adaptive capacity at the national level can be borrowed easily from other data sources for an initial holistic assessment of generic adaptive capacity (Downing et al., 1997). Adaptation efforts by governments and civil society must be targeted at specific groups within vulnerable countries, and further research into the underlying causes of vulnerability at the sub-national scale are necessary (Burton, 2001; IPCC, 2001; Jones and Boer, 2003; Adger et al., 2004).

The climatic stimuli and their responses for a particular locale, activity or social grouping can be used to construct a coping range if sufficient information is available. The coping range is a template that is particularly suitable for understanding the relationship between climate hazards and society. It can be utilized in risk assessments to provide a means for communication and, in some cases, may provide the basis for analysis (Burton, 2001; Jones, 2001).

It is important to understand the boundaries of systems' coping ranges – thresholds beyond which the consequences of experienced conditions become significant. Judging adaptive capacity depends upon both defining a coping range and understanding how the efficiency of any coping strategy might be expanded by adopting new or modified adaptations (Smit et al., 2000). The coping range is usually specific to an activity, group and/or sector, though society-wide coping ranges have been proposed (Yohe and Dowladabadi, 1999; Yohe and Tol, 2002).

Critical thresholds are defined as any degree of change that can link the onset of a critical biophysical or socio-economic impact to a particular climatic state (Pittock and Jones, 2000). Critical thresholds can be assessed using vulnerability assessment and mark the limit of tolerable harm (Smit et al., 1999; Pittock and Jones, 2000). For any system, a critical threshold is the combination of biophysical and socio-economic factors that marks a transition into vulnerability. The construction of a critical threshold can be used to limit the coping range. If this threshold can be linked with a level of climate hazard, then the likelihood of that threshold being exceeded can be estimated subjectively if the relationship is known qualitatively, or calculated if the relationship is quantifiable (Cai and Smit, 1996; Feenstra et al., 1998; Jones et al., 2002; Liu, 2002).

Agriculture is an important sector of the economy in Northeastern China that is sensitive to climate change. Projected changes in climate are likely to have both positive and negative effects on agriculture in the region (Lin et al., 2004). The purpose of this paper is to evaluate the adaptive capacity to climate change on agriculture in the Northeastern China by assessing the socio-economic coping capacity and its indicators; and to examine the feasibility of the analytic hierarchy process (AHP) method in determining the weights and the values or scores for adaptive capacity indicators.

2. Methodology

2.1 Background of case study region

Northeast China is located in the northern part of the natural realm of Eastern Monson China, and comprises of Heilongjiang, Jilin and Liaoning Province and part of the Inner Mongolia Autonomous Region. The area totals about 800,000 km2 and has a human population of about 106 Million (1999). Northeast China plays a vital role in China's economic development with its fertile land, developed industry and higher urbanization. It is one of the most important suppliers of commercial food grains and economic crops (soybean, sugar beets, etc.) in China. Northeast China, which has a full set of industrial bases, will be coming under the domestic and overseas spotlights in the near future. As transportation networks and capital goods manufacturing develop in the future, this area is largely expected to grow by leaps and bounds.

Northeast China is a hot spot of land use, partly because of its relatively high food production potential, and partly because of its rapid socio-economic change. Studies in China project that northeast China is one of the regions most vulnerable to warming temperatures (Zhang and Wang, 1993). The following are some projections of climate change impacts in northeast China:

- Increase in temperature, and either an increase or decrease in precipitation resulting in flooding or eventual water supply shortages;

- Increase in severity and frequency of extreme weather such as damaging floods and droughts;
- Crop production will be affected on remaining arable land. However the predicted impacts to crop yields vary widely due to the uncertainty around water supply and the possibly positive effects of CO_2 on production practices;
- Large shifts in the remaining boreal forests and increased forest fire and desertification; and
- Wider distribution of many vector-borne diseases.

The key social vulnerabilities in the region are:

- Where resource-dependent communities have their resilience undermined by increased exposure to the physical stresses in water availability, agricultural impact, and other sensitivities; and
- Where sustainability and equity (Munasinghe, 2000) are sacrificed for economic growth, exposing larger parts of the population to impacts.

Research indicates that northeast China is one of the warming areas in China over the last 100 years (Ding, 2003). The annual precipitation has been decreasing since 1965 while average temperatures have risen by up to 1 degree Celsius. Warmer and drier trends are very significant in the recent decade. Temperature increases occur mainly in winter, while annual totals of precipitation have decreased in Northeast China due mainly to changes in summer precipitation (Zhai et al., 2003).

Previous studies on the region suggest that, in general, areas in the mid to high latitudes will experience increases in crop yield. Climatic variability and change will endanger sustained agricultural production in the region in the coming decades. The scheduling of the cropping season as well as the duration of the growing period of the crop also would be affected (Tshinghua University, 1999; Zhang et al., 2003; Lin et al., 2004).

The observed impacts of changes in regional climate warming that are relevant to agriculture are related to increasing yield trends in Northeast China. With the expansion and advancement in phenologies of agricultural pests, rice, wheat, and corn production could meet adverse impacts as well as shortened growth periods caused by a continuously warming climate (Zhang et al., 2003; Lin et al., 2004; CCChina, 2004).

2.2 Process of adaptive capacity assessment

In order to determine the weights (wi) and the values or scores for the adaptive capacity indicator, the analytic hierarchy process methodology has proved to be an extremely useful tool.

The Analytic Hierarchy Process (AHP) methodology is particularly convenient for comparing different investment alternatives and is a well-known tool for decision-making in operational analysis. It has been applied mostly for decision making in operational and risk analysis for evaluation of project alternatives and to a lesser degree in evaluation of environmental consequences. Researchers have used the AHP methodology for a combined cost–benefit analysis and environmental assessment of a petroleum pipeline project. This methodology was applied for comparing four different locations for a domestic airport in Iceland from the economical and environmental point of view. The AHP methodology is based primarily on comparison values instead of on assessing scores and weights directly. The numerical scale used is 1–9, where 1 is the "equivalent" value/importance, 3 is a "slightly" superior value/importance, 5 is "some" superiority, 7 is "considerable" superiority and 9 is "outright" superiority, with the even numbers in between applied if necessary. The calculation process can be described as follows:

STEP 1: To obtain the weights, wi, to be associated with each adaptive capacity factor, form the comparison matrix A. Each factor is compared with all other factors on a numerical scale (described above) according to importance. If the comparison is consistent, the elements {aij} will satisfy the conditions: aij = wi/wj=1/aji, aii = 1.0, aik_akj = aij, (i, j, k=1, 2, . . . n).

STEP 2: For each of A's columns, divide each entry by the sum of entries of the corresponding column. This yields a new matrix Anorm, in which the sum of the elements of each column vector is 1.0.

STEP 3: By forming the average value of all elements in a row, an estimate of the "best" value for the vector of the weights, w*={wi*},is obtained. As the comparison values are selected without due considerations of the conditions in Step 1, they are bound to be both biased and inconsistent. However, the averaging method reduces such inconsistency and bias.

STEP 4: It is necessary to check the consistency of the solution obtained in Step 3. Firstly, all rows of A are proportional to the first row. Therefore, if wT={w1, w2,. . . wn} is the vector of the weights, AwT = nw, where n is the number of environmental factors involved. Thus, for perfect consistency, the vector of weights will be one of the eigenvectors of A and n is one of the eigenvalues. Actually, since all rows are dependent, the rank of the matrix A is one. Secondly, the trace of the comparison matrix A is the sum of all eigenvalues, i.e. should be equal to n since all other eigenvalues are zero as the rank of A is one. The actual vector w* obtained in Step 3 differs from the "consistent" eigenvector w, whereby Aw * T = kw*. Since w* is not perfectly consistent, k6 n. From the above relation, k can be calculated and should not differ much from n. The difference (k_n) is the consistency condition. The consistency index (CI) is then defined as the relative fraction CI=(k_n)/(n–1), which is equivalent to the standard deviation of the evaluation error and the mean deviation of each comparison element aij from the true ones. Now, introduce the random index (RI), which is defined as the mean deviation of randomly selected comparison values aij from the true ones. The consistency ratio, CR = CI/RI, should be less than 0.1 for all matrices A with n>3 and less than 0.08 for n = 3 to yield satisfactory results.

STEP 5: Repeat the same process for each of the environmental factors for all three alternatives to obtain the scores or values of the utility functions. The main problem is to provide impartial and consistent comparison values. There are many methods for avoiding inconsistency and biased comparison of the environmental factors. For instance, one person may be an "environmentalist" and overemphasize nature conservation in comparison with other factors. Another person is economically minded and will have a tendency to prioritize economical factors at the cost of environmental ones. This is well known, and no two individuals will make the same decision regarding comparison values. One way is to set up a broad panel of experts and have them reach a consensus regarding the comparison values and scores. This is wrought with all kinds of problems related to consensus reaching and dominant personalities. The Delphi method tries to avoid this by having the individual experts work independently of each other and let the coordinator form a final consensus. Another way is to let various individuals rate the different alternatives and transform the averages to relative values.

2.3 Analytic Hierarchy Process (AHP) software

In this case study, the commercial AHP software, Expert 2000, was used to conduct analysis in the expert workshop and in-house post-processing. The following features in this software package specifically address the above discussions:

1. There are three different paired comparison types, Importance, Preference and Likelihood. Importance is most appropriate when comparing objectives or criteria. Preference is appropriate when comparing alternatives with respect to their covering objective. Likelihood is appropriate when comparing the likelihood of uncertain events or scenarios, such as in risk analysis.
2. There are three pairwise comparison assessment modes. Verbal judgments are used to compare factors using the words Equal, Moderate, Strong, Very Strong, Extreme. Equal requires no explanation. Extreme means an order of magnitude – about 9 or 10 to 1. Judgments between these words, such as Moderate to Strong are also possible. Graphical judgments are made by adjusting the relative length of two bars until the relative lengths of the bars represent how many times more important one element is than the other. Numerical judgments are made using a nine-point scale, representing how many times one element is more important than another.
3. The inconsistency measure is useful for identifying possible errors in judgments as well as actual inconsistencies in the judgments themselves; this is accessed from the Priorities Window of the software. Inconsistency measures the logical inconsistency of your judgments. For example, if you were to say that A is more important than B and B is more important than C and then say that C is more important than A you are not being consistent. A somewhat less inconsistent situation would arise if you would say that A is 3 times more important than B, B is 2 times more important than C, and that C is 8 times more important than A. In general, the inconsistency ratio should be less than 0.1 or so to be considered reasonably consistent. The priority window also shows how many missing judgments are in the set of objectives being compared.

2.4 Comparison of results

As already mentioned, the decision making involved in forming the comparison matrix need not be perfect, that is, consistent in the sense that all conditions listed under Step 1 are fulfilled. However, the AHP method systematically reduces built-in bias and renders good estimates for the weights and the scores. In this study, nine different individuals (AC1– AC9, see Table 1), the authors being AC1, provided comparison values independently of each other. The comparison framework as outlined above was carefully explained to each evaluator, who were asked to quantify accordingly the comparison values for all environmental factors and alternatives.

Table 1 Adaptive capacity indicators and their weights

INDICATORS OF ADAPTIVE CAPACITY	WEIGHTS
Gross domestic product (GDP) per capita	0.296
Gross output value of farming, forestry, animal husbandry and fishery	0.031
Gross industrial output	0.288
Area of cultivated land under management per capita	0.031
Irrigated area per capita	0.080
Total power of agricultural machinery	0.078
Electricity consumed in rural area	0.093
Consumption of fertilizers	0.062
Output of major farm crops per capita	0.040

2.5 Data sources and database

The data used for the indicators are mainly taken from the “Statistical Year Books” of Liaoning, Jilin, Heilongjiang province and Inner Mongolia Autonomous Region respectively from 2001 to 2003. The selected indicators are determined by consulting results of expert workshop and by data reliability and accessibility. The database for Web-mapping and geographic information system (GIS) model was created.

3. Results and discussion

The adaptive capacity is divided into five grades according to the calculated relative values of the indicators. Their classification is shown in the Table 2.

Table 2 Classification of the adaptive capacity

ACp	0 – 20	20 - 40	40 - 60	60 - 80	80 – 100
Grade	1	2	3	4	5
	Weakest	Weak	Medium	Strong	Strongest

The preliminary results of the present adaptive capacity in the Northeastern China are shown in Figure 1.

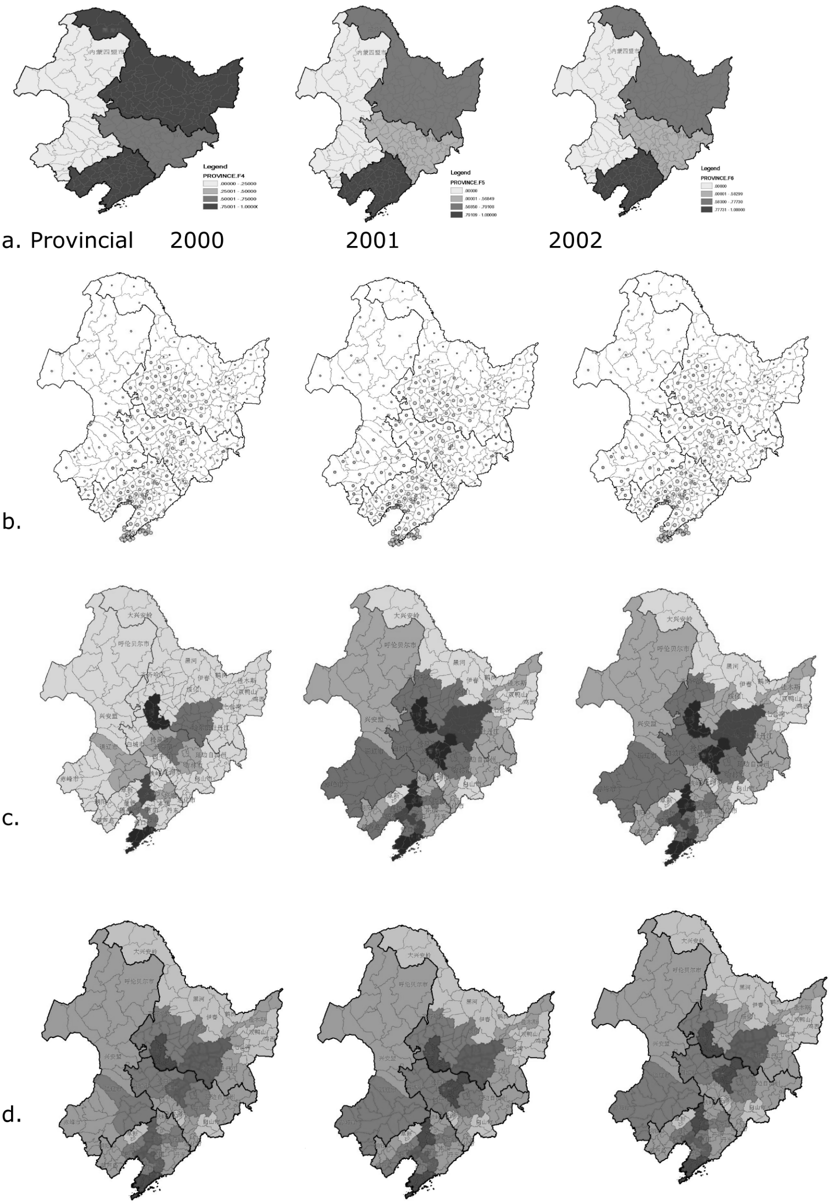
The assessment of adaptive capacity is conducted at three levels – the provincial, county and regional level. In the provincial level, the Laioning province has the strongest adaptive capacity and the eastern parts of the Inner Mongolia Autonomous Region show the weakest adaptive capacity. The Jilin province has a medium adaptive capacity while the Heilongjiang province has a strong adaptive capacity in the in the years 2001 and 2002. In the year 2000, both the Liaoning and the Heilongjiang provinces show the strongest adaptive capacity (Figure 1a).

In the county level the counties in the Eastern Liaoning Peninsula, in the Changchun region, in the Daqing region and in the Harbin region show the strongest adaptive capacity. The weakest adaptive capacity counties are distributed in the eastern parts of the Inner Mongolia Autonomous Region, in both western and eastern Jilin and Heilongjiang provinces, where most of the counties are mountain and forest regions. The results for the years 2000 to 2002 show the same tendency (Figure 1b).

The same is shown at the regional level as in the county level. The Eastern Liaoning Peninsula, Changchun region, Daqing region and Harbin region have a strongest adaptive capacity, where the industry is much stronger than other regions in the Northeastern China (Figure 1c).

By the classification of adaptive capacity the regions with the strongest adaptive capacity are distributed in the regions with strong industry and wealthier economics (Figure 1d).

The study has shown that economic, institutional, political, social factors are likely to play an important role in enabling the agricultural sector to adapt to climate change. Strong industry and trade make regions such as Dalian and Daqing register a higher adaptive capacity, where GDP and gross industrial output are higher than in the other regions in Northeastern China. All of the province capitals, the political and social centers, have a strong adaptive capacity. The remote mountain areas, grassland and forest region have a relatively weak adaptive capacity.



a. Provincial 2000 2001 2002

b.

c.

d.

FIGURE 1

Adaptive capacity in the Northeastern China

It is not sufficient to identify the vulnerability of a system to climate change by assessing the present adaptive capacity, since the climate and socio-economic scenarios are not combined with the assessment proceeding.

4. Concluding Remarks

The Analytic Hierarchy Process methodology is particularly convenient for comparing different investment alternatives and is a well-known tool for decision-making in operational analysis. The AHP method has proved to be an extremely useful tool and systematically reduces built in bias and renders good estimates for the weights and the scores.

The economics, institutional, political, social factors are likely to play an important role in enabling the agriculture sector adapt to climate change. The regions with relative strong economics are likely to have a strong present adaptive capacity.

The present adaptive capacity was evaluated in this study, but it is not sufficient to identify the vulnerability of a system to climate change by assessing the present adaptive capacity, since the climate and socio-economic scenarios are not combined with the assessment proceeding.

Future work should build upon this analysis by examining case studies at the sub-regional level in order to determine to what extent the results obtained here may be generalized. While indicators have their role to play, they can only capture the most general aspects of adaptive capacity when applied at the regional level. It is, therefore, important to develop our understanding of vulnerability by examining how it arises in a variety of contexts, paying attention to the relative importance of various social, economic, political, geographic and environmental factors in different counties, and also to the hazard-specific nature of vulnerability. The exploration of regional climate and socio-economic scenarios, and assessment of adaptation options need to be enhanced by vulnerability assessment proceeding.

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