Desertification Control and Sandstorm Mitigation in the Area Encircling Beijing - with a Discussion on the Application of Bayesian Network and Hydrological Modeling

Yang H.
Swiss Federal Institute for Environmental Science and Technology,
Uberlandstrasse 133, 8600 Dubendorf. E-mail: hong.yang@eawag.ch

Abbaspour, K. C.
Swiss Federal Institute for Environmental Science and Technology,
Uberlandstrasse 133, 8600 Dubendorf. E-mail: abbaspour@eawag.ch

Zhang Y.L.
Institute of Geographic Science and Natural Resources Research,
Chinese Academy of Sciences. E-mail: Zhangyl@igsnrr.ac.cn

Abstract: Desertification has drawn much concern in China amid a string of strong sandstorms hitting Beijing in recent years. Returning farmland to forests and grasslands around Beijing has been taken as a key measure to tackle the problem. This paper examines the causes of desertification and favored measures in dealing with the problem from the perspective of locals using a case study for three counties in northern Beijing. The results suggest that returning farmland to forests and grassland has received a wide support in the areas concerned. Such a support, however, is partly backed by the economic benefits the locals have received or expected to receive from the central government. The effectiveness of the measure in mitigating Beijing's sandstorms may, however, be limited. Meanwhile, hydrological and environmental impacts of the measure on the downstream areas, notably Beijing, are also not clear. In order to clarify these ambiguities, this paper proposes to apply a Bayesian network to estimate the risk of desertification and a model approach to quantify the effects of land use changes on hydrological systems and the environment for the entire watershed.
Keywords: sandstorm, desertification, Beijing, 'rain for green' Bayesian network, hydrological modeling

1 Introduction

All the information from local and international sources indicates that desertification has been accelerating in most parts of the world, despite the implementation of various practices to combat its expansion. One of the consequences of desertification is the intensification of sandstorms. In China, it is estimated that nearly a third of the territory are plagued by rampant desertification. Every year, deserts eat up 2,460 square km of land (Fan and Zhou, 2001). Alongside the desert advances, there has been a dramatic increase in the frequency and intensity of sandstorms in northern China, notably in Beijing. In the year 2000, the city bore the brunt of such storms 18 times (China Daily, 2002). The problem has attracted a serious attention partly due to the bad image it has given to Beijing. The high public attention, however, is also as a result of the increasing public awareness of environmental issues with the country moving steadily towards economic prosperity.

There has been considerable debate on the causes of desertification. The general conclusion is that desertification processes can have both natural and man-made causes. Historical observation records show that northern China has become drier and warmer during the past three to four decades. The changing climate has sent stronger winds to the north each spring, increasing the fragility of the ecosystem (Ministry of Science and Technology, 2000). On the other hand, numerous evidences have shown that desertification has been related to relentless land reclamation, deforestation and over-grazing, which have led to a rapid disappearance of vegetation covers. Strong sandstorms have caused serious

damage in the areas affected. It is estimated that the direct financial losses caused by sandstorms in recent years amounted to 54 billion Yuan annually (Xinhua News Agency, 2000)

The severe economic and environmental damages of sandstorms, together with giving of a bad international image to the capital of the nation, have urged the Chinese government to tackle the problem. A series of projects aiming to combat desertification and sandstorm have been launched. Building an ecological shelterbelt around Beijing to prevent the invasion of sandstorm is one of them. Central to the project is a land conservancy program that involves a return of farmland to forest and grassland in the areas targeted. Farmers are compensated with grain and cash according to the size of the land they put aside. The idea is simply to use 'grain' in exchange for 'green' Given the political profile of Beijing, the project is also called 'image project'.

This study examines the perception of local villagers to the natural and human causes of desertification in the project-targeted areas using a case study for three counties north of Beijing. A household survey is conducted to elicit farmers' perspective on the causes of the problem and measures to deal with it. Public acceptance to the 'grain for green' policy and reasons behind it are also sought. This is followed by a discussion of the possible hydrological and environmental impacts of the measure. A Bayesian network is proposed for estimating the risk of desertification and a modeling approach is suggested for quantifying the impacts of land use changes on the hydrological system and the environment in the watershed.

2 Natural and social economic conditions of the case study counties

2.1 Natural and environmental conditions in the case study counties

The three counties: Huailai, Zhangbei and Fengning, are located in the temperate continental monsoon climate zone. Cold and windy winters and warm and dry summers are the general characteristics of the climate. The annual average rainfall ranges between 300 mm and 600 mm (Ministry of Civil Affairs and Ministry of Construction, 1992). Most of the rain comes between May and August. Lack of water is a common predicament in the three counties. Agriculture is mainly rain-fed and irrigation is only available in limited areas and for commercial crops. Droughts, especially during spring, often cause crop failures. Strong wind in winter and spring is also a common hazard. Meanwhile, the strong wind blows away the topsoil, reducing the land productivity. It also facilitates desert advance and intensifies sandstorms/duststorms both locally and in the surrounding areas, particularly Beijing and Tianjin (Ministry of Science and Technology, 2000). Overgrazing, reclaiming grassland for farmland and deforestation have worsened the problem.

Situated in the northwest of Beijing and Tianjin, the geographical links between the three counties and the two economic centers are intrinsic. Fengning is the origin of the two major rivers: Chaohe and Baihe, that supply drinking water to Beijing and Tianjin, respectively. The Miyun reservoir in the county provides about 80 percent of the water supply to Beijing, with the rest coming mostly from the reservoir in Huailai. Zhangbei is the mouth where boreal winds come in and blow towards southeast into Beijing and Tianjin. Environmental degradation, desertification and deforestation in these counties impose strong impacts on the two cities, worrying the central government and the local governments in the two municipalities.

2.2 Socio-economic conditions

In spite of their proximity to Beijing, the economic development in the three counties is retarded. Fengning and Zhangbei are among the poorest counties in the nation. Agriculture and animal husbandry are the major sectors of the economy. Industrial and service sectors account for only a small potion of the GDP. Village level industries are virtually absent. The larger share of the primary industry in total GDP in Zhangbei suggests its higher dependence on agriculture, a sector relying heavily on natural resources. Although the figures of arable land in the three counties are above the national average, their crop yields are generally low. This is particularly so in Zhangbei and Fengning.

3 Causes of desertification and mitigation plans in the case study counties

3.1 Perceived causes of desertification

The climate records have shown that in the region where the three counties are located, the climate has tended to become warmer and drier during the last 50 years. Although the rainfall did not record a significant decline, the aridity index (the ratio of potential evaporation to effective rainfall) increased due to the higher temperature and thus greater evapotranspiration (Ministry of Science and Technology, 2000).

Apart from the climate change, there are a number of other factors that have been considered to be responsible for intensification of desertification and sandstorms in the three counties. Official documents of the three counties identified the following causes: Huailai - topography (giving rise to strong invading winds), sand sediment in rivers, land reclamation, over grazing and reduction of arable land due to the construction of the Guanting Reservoir. Zhangbei - topography, low vegetation coverage, droughts, land reclamation and over grazing. Fengning - fragile ecosystem, poverty, land reclamation and over grazing (Huailai Government, 2001; Fengning Government, 2001 and Zhangbei Government, 2001). It is noticeable that all the three counties have considered land reclamation an important cause of the intensification of desertification and sandstorm. However, official statistics of the three counties all show a decrease in arable land areas and agricultural sown areas during the last two decades. This situation may imply that land reclamation has a delayed effect on desertification and manifests itself only after a number of years.

Over the years, the overall environment in the three counties has been deteriorating. One of the consequences has been the expansion of desertification. Currently, over half of the area of Zhangbei County is affected by desertification. In Huailai and Fengning, the affected areas are also substantial, 18 percent and 33 percent, respectively (Huailai Government, 2001; Fengning Government, 2001 and Zhangbei Government, 2001).

3.2 Counter-measures and difficulties

In accordance to the launch of the project of anti-sandstorm shelterbelt around Beijing, the governments of the three counties have stipulated their own action plans for mitigating desertification and sandstorms. By and large, the measures specified in the plans include: (1) returning a substantial amount of farmland to forests and grasslands; (2) assuring the survival of planted trees and grasslands; (3) protecting forests and grasslands from reclamation; (4) developing intensive agriculture and animal husbandry; and (5) developing the sand industry (including eco-tourism) (Huailai Government, 2001; Fengning Government, 2001 and Zhangbei Government, 2001). Exploiting water resources and developing irrigation are at the core of the development of intensive agriculture. Other associated inputs, fertilizer and pesticide, are also to be increased. For intensive animal husbandry, stall-fed animal husbandry is called upon to replace the traditional rangeland activity.

In the action plans, the three counties invariably claimed that they are one of the major sources of sandstorm in Beijing. Therefore, Beijing would be the primary beneficiary to the implementation of the above measures. By building a green shelterbelt for the capital, they will return to Beijing ‘a piece of blue sky and a basin of clear water’.

Nonetheless, to carry out the above measures, a big capital investment is required. As all the three counties are poor, though the degree varies, they all emphasized the financial difficulties in their plans and appealed for financial support from the central government and compensation from Beijing.

4 Farmers’ perspective on desertification and acceptance to the ‘grain for green’ policy

4.1 General characteristics of the three villages

To gain insights into farmers’ perspective on desertification and measures to deal with it, three poor villages in the respective counties were selected for a household survey. They are Panchangying

(Zhangbei county), Longbaoshan (Huailai county), and Langtougou (Fengning county). The three villages are known for their inhospitable natural conditions and severe desertification. A summary of the survey is presented in Table 1.

Table 1 Public perception of environmental degradation and acceptance of the counter-measures

Questions	Longbaoshan	Panchangying	Langtougou
What is the main reason(s) for the intensification of desertification?*	Increasing aridity of climate: 90% Land reclamation: 10% Overgrazing: 0 % Population growth: 0% Desert advance: 20%	Increasing aridity of climate: 90% Land reclamation: 0% Overgrazing: 20% Population growth: 10% Desert advance: 0%	Increasing aridity of climate: 70% Land reclamation: 25% Overgrazing: 55% Population growth: 35% Desert advance: 15 %
What are the most effective measures in dealing with desertification?	Planting trees and grasses: 100%	Returning farmland to pasture and forests: 100%	Returning farmland to pasture and forests: 100%
Do you like the 'grain for green' policy	N/A	Yes: 100% No: 0%	Yes: 100% No: 0%
What measures do you use to increase the production on your land?*	Increase fertilizer: 40% Develop irrigation: 40% Apply new varieties: 40% Land reclamation: 10%	Increase fertilizer: 60% Develop irrigation: 15% Apply new varieties: 40% Land reclamation: 15%	Increase fertilizer: 60% Develop irrigation: 35% Apply new varieties: 50% Land reclamation: 5%

*The sum of the percentages in each village is over 100 percent. This is because some interviewees pointed out more than one reason and measure.

The household survey results indicate clearly that the intensification of desertification has been very apparent to villagers. An overwhelming majority of the interviewees considered the increasing aridity of the climate as an important reason for the aggravating desertification. This is consistent with the climate change records in the region. Other important factors causing desert advancement included population growth, overgrazing, and land reclamation. It is noted, however, that a relatively small percentage of the farmers interviewed considered land reclamation an important factor for the intensification of desertification. This is in contrast to the statement of the governments of their counties. The explanation to this situation is that the rapid expansion of agricultural land in the three villages occurred in the 1960s and 1970s. Since the 1980s, the reclamation has dampened. Due to the population growth, the agricultural land on a per capita basis has been declining.

Planting trees and grasses are invariably considered as an effective measure in dealing with desertification in the three villages. This may be partly due to the fact that so far it has been the only measure applied in combating desertification in the these villages.

To build the anti-sandstorm shelterbelt around Beijing, Panchangying and Langtougou have been designated as experimental sites for the 'grain for green' policy since 2001. Households are compensated with approximately 100 kg of grain and 20 Yuan of cash for each Mu (one fifteenth of a hectare) of land they return to trees or grasses. As the amount of grain compensation exceeds the average yield of the land put aside, in the survey we found that farmers are generally satisfied with the grain compensation. However, they complained about the meager cash compensation and the stringent restriction on the animal husbandry outside of their household compounds. Leaving the villages to seek non-agricultural jobs becomes the only option for farmers to get additional cash income. Among the households surveyed, a large percentage of the families have at least one member working outside the villages. With more farmland to be returned to trees and grasses in the areas, it is expected that the flux of exodus will increase. Most of them would choose Beijing as their destination. This could put a pressure on the

employment and environment in the city. So far, however, this issue has been ignored in the efforts to tackle desertification and sandstorms.

5 Modeling effectiveness of the measures and their hydrological impacts

Although the 'grain for green' policy has received a wide public support as a measure to deal with desertification and sandstorm around Beijing, some questions remain and need further scrutiny. These include the effectiveness of the measure on sandstorm mitigation, complexity of causes of desertification and hydrological and environmental impacts of the land use change in association with the implementation of the policy. This section discusses these issues.

5.1 Sources of sandstorm

The three counties all claimed that they are one of the major sources of the sandstorm in Beijing. A project report from the State Environmental Protection Administration, however, showed that 56% of the sandstorms that hit Beijing are mainly originated in southern parts of Mongolia. The remaining 44 percent came mostly from the Inner Mongolia Autonomous Region (China Daily, 2002). If this is true, the effect of implementing 'grain for green' policy in the areas around Beijing on curbing the sandstorm may be limited, although it is noted that the increase in vegetation coverage along the route of the storms may reduce their severity.

5.2 Application of the bayesian network method to desertification studies

Causes of desertification are multifaceted. Although advances have been made, the understanding of the interaction amongst different factors is rather inadequate. It can be argued that better progress could have been achieved if more desertification studies had involved interdisciplinary data analysis. Such an integrated approach has been hampered primarily by the lack of mathematical framework that facilitates interdisciplinary data collection and analyses. Bayesian network (Jensen, 2001) can provide such a framework, allowing a simple, integrated methodology for the modeling of complex systems.

Figure 1 presents a simplified network for desertification. Table 2 gives the network's state information, which was designed to represent the three villages considered in this study. Primarily it is assumed that the government is providing some advisory services, probability of poverty and population pressure is high, the conditional probability of overgrazing is assumed to be higher when poverty and population is high. The link between the variables of the network was initially defined using a combination

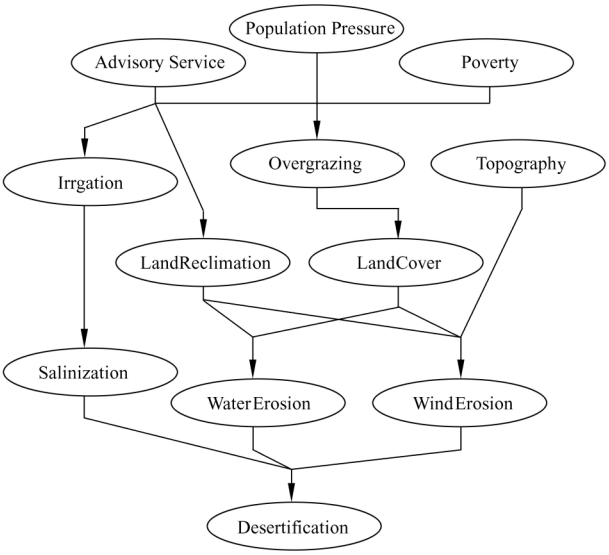

Fig. 1 A simplified Bayesian network for desertification

of available data and our own expert knowledge gained during the literature review and interviews. The network as presented is a relatively simple representation of the variables and the relationships that influence desertification. It is recognized that other variables can impact desertification and a much more complex network could be created. This said; we could test the proposed measures of combating desertification by the governments of the three counties by changing the variables of the devised network in Figure 1. The net effect of the proposed measures is to increase the land cover and irrigate intensively. Increasing the land cover will decrease the risk of wind and water erosion, which in turn will decrease the desertification risk. Increasing the irrigation however, may increase the risk of salinization and consequently increase the desertification. Nonetheless, the net effect should be in favor of reduced desertification risk. By implementing the proposed measures, the initial belief of the risk of desertification being high decreased from 0.718 (Table 2) to 0.622, which is an improvement.

Table 2 Probability of different states in the belief network of Figure 1

Variable	State 0		State 1		State 2	
Population pressure	Low:	0.052	Medium:	0.104	High:	0.844
Advisory service	Available:	0.600	Not available:	0.400		
Poverty	Low:	0.300	High:	0.700		
Overgrazing	Sustainable:	0.200	Unsustainable:	0.800		
Land reclamation	Yes:	0.500	No:	0.500		
Irrigation	Yes:	0.150	No:	0.850		
Land cover	Low:	0.685	High:	0.315		
Salinization	Low:	0.177	Medium:	0.373	High:	0.450
Water erosion	Low:	0.407	High:	0.593		
Topography	Favorable:	0.200	Unfavorable:	0.800		
Wind erosion	Low:	0.414	High:	0.586		
Desertification	Low:	0.117	Medium:	0.165	High:	0.718

5.3 Hydrological modeling to study the effects of management measures

As mentioned earlier, the three counties planed to develop intensive agriculture and animal husbandry to compensate the losses of agricultural production incurred as a result of the return of farmland to forest and grassland. Intensive agriculture requires more intensive use of chemical fertilizer and irrigation. It is not clear what effects such measures could have on the hydrology and the environment of the watershed. As Beijing is in the downstream of the watershed, these effects deserve a more rigorous study. So far, the understanding on the issues has been very limited partly because of the lack of integrated approaches. Hydrologic programs such as SWAT (Soil and Water Assessment Tool) (Arnold *et al*., 1998) may help in quantitatively measuring the effects of changing landuse and agricultural practices on surface and groundwater flows as well as the fate and transport of chemical substances.

An important step in the development of a Bayesian network, and one of its weakest points, is the elicitation of conditional probabilities between causes and effects. In desertification studies, hydrologic simulation programs such as SWAT could be used to develop the conditional probabilities. For example, the effect of topography and land cover on wind and water erosion could effectively be simulated. This would remove a reliance on expert opinion for the development of the links in the network.

6 Concluding remarks

The ‘grain for green’ policy has received a wide public support as a measure in tackling desertification and mitigating sandstorm around Beijing. The compensation from the central government has played a vital role in the smooth implementation of the measure in the targeted areas. With the return of farmland to trees and grasses, the desertification in northern Beijing is likely to be alleviated.

However, there are some remaining questions that need attention amid the generally supportive atmosphere. For example it is not clear what impact the changes in land use may have on the hydrology

and ecosystem of the watershed. Also, the increase in the intensity of agriculture will increase the application of fertilizer and pesticides, which may have adverse effects on the quality of surface and ground water. The exploitation of surface and groundwater associated with the intensive agriculture may reduce the water supply in downstream areas, i.e., Beijing and Tianjin. Meanwhile, as the sources of the sand are overwhelmingly 'external', the 'grain for green' policy may only have limited impact on the mitigation of sandstorms in Beijing.

Acknowledgement

This study was funded by the National Key Project for Basic Research (G1998040814) and the Key Projects of IGSNRR, CAS for Basic Research (CXIOG-E01-01 and CXIOG-A00-03-02) in China and the Swiss Federal Institute for Environmental Science and Technology (1203.34) in Switzerland and the Alliance for Global Sustainability (AGS/84321). We thank Professor Li Xiubin for the insightful suggestions to the study. Thanks are also due to Dr. Wu Shaohong for helping select the study sites. We also thank Professor Liu Changming, for helpful discussions.

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