From innovation to adaptation: A 30-year SEE lesson from the evolution of saline-alkali soil management in Manasi River watershed, China

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Abstract
Previous studies on saline-alkali soil management mostly followed an instrumental "prediction and control" approach dominated by technical end-of-pipe solutions. However, those "integrated" instrumental solutions frequently perished due to the growing social & economic uncertainties in financial support, legal insurance, expertise service and other factors. This investigation summarizes the 30-year period of saline-alkali soil management – the social and economic and ecological (SEE) management innovation – its adoption, diffusion, adaptation and transformation in Manasi River watershed of northern Xinjiang. This area was experiencing three distinct SEE management stages over last three decades: preliminary development of instrumental desalination techniques with little support from SEE system from 1978 to 1988; rapid development of integrated instrumental and engineering desalination technique system but still separating from social policy and economic system from 1989 to 2000; and only in the recent decade have successful practices of integrated desalination technique system been achieved following the transformation of local SEE supporting system to collaborate well with instrumental approaches. The results of GIS analysis (Fragatats 3.3) and historical documents provide data evidence for above three transition stages. The total area of saline and alkali land was increased by 32.7%, 47.6% during the first two decades but decreased by 11.9% in the recent decade. The numbers of saline land patches were 116, 129 and 121 in 1989, 2000 and 2007 respectively, a similar trend to the changes of total area. However, both perimeter-area fractal dimension (PAFD) and splitting index (SI) continued to increase, with values of 1.265, 1.272 and 1.279 for PAFD and 259.29, 269.68, 272.92 for SI in 1989, 2000 and 2007, respectively. It suggests that saline and alkaline land distribution had been fragmented, and sequestrated into salt micro-catchments within whole oasis ecosystems. This case is largely associated with effective adoption of integrated engineering and biological desalination programs as a result of local SEE saline-alkali soil management innovation.

Key Words
Social & economic & ecological (SEE) system, saline-alkali soil, instrumental solution, innovation, China.

Introduction
'It seems to me that the nature of true tragedy is when something is so badly broken that with the best will in the world, you can't put it back together again and what was broken has to stay broken' (Presentation by Salman Rushdie, 29 August 2005 and cited by Weinstein 2008). Manasi River watershed is located in northern Xinjiang of China and is a typical arid oasis ecosystem. Before 2000-year, saline affected farmland area was up to 47.9% of total farmland area due to inefficient water resource management strategy (cited from local government official document 2008). Unreasonable water resource utilization was a main driving force to induce the formation and aggravation of soil salinity and alkalinity in arid/semiarid oasis ecosystem (Jolly *et al.* 2008). Aggravation of salinization seemed to bring local agricultural production, social-economic development and even human habitation into irreversible ecological crisis. High groundwater level and excessive surface water consumption were the major natural factors causing this crisis. Although some instrumental solutions started to be put into practice from 1990 to 2000, the salinized area still increased from 850 km^2 to 1254 km^2 as a result of lacking enough supports and interactions from social-economic and policy systems. Initially, water resources management followed an instrumental "prediction and control" approach dominated by technical end-of-pipe solutions (Pahl-Wostl *et al.* 2008). Relevant efforts were paid on salineland management using instrumental or purely engineering approaches in saline affected area (Luedeling *et al.* 2005). However, this approach no longer works well, because it cannot adequately deal with the growing uncertainties, different stakeholder perspectives and growing interdependence that are characteristic for today's resource management issues (Pahl-Wostl *et al.* 2008). New approaches can be

found only within the framework of coupled human and natural systems (CHANS). The CHANS has been experiencing unprecedented rapid changes and progressively tighter couplings at multiple scales (Liu *et al.* 2007).

Since 2000, local government issued a series of reclamation and management policies and measures including legal regulations of water allocation and water quality monitoring, administrative policies of irrigation engineering and technical program, economic regulations on land use and management, social organizations of community participative water management association and scientific technical standards of farmland drainage and irrigation, etc. The updated management system enabled pure instrumental and engineering solutions to a successful saline & alkali soil reclamation practice. Putting the knowledge gained from such integrated studies into social, economic and environmental (SEE) decision-making processes is essential for achieving productive and sustainable CHANS (Liu *et al.* 2007). The objective of this study is to conclude a successful practical case about integrated SEE technique to optimize water utilization system, restrain saline land enlargement and obtain sustainable human-nature relationship.

Methods

Study sites

Manasi River watershed is located at the north Xinjiang of China (85°01′ - 86°32′E, 43°27′ - 45°21′N) with the total area of $2.43*10^4$ km^2, geographically originating from the northern Tianshan Mountain and mainly covering Shihezi city, Shawan county and Manasi County of Xinjiang (Figure 1). It is adjacent to the southern Gurbantunggut Desert and belongs to typical arid oasis ecosystem with l10-200 mm annual precipitation. Historically, this area was a nomadism oasis which started to be exploited as agricultural reclamation area since 1955. The total population increased from about 50,000 at that time to a current population of 910,000. Agricultural production is the main resource of local GDP and the water consumption of agriculture accounts for 90% of total water resource use.

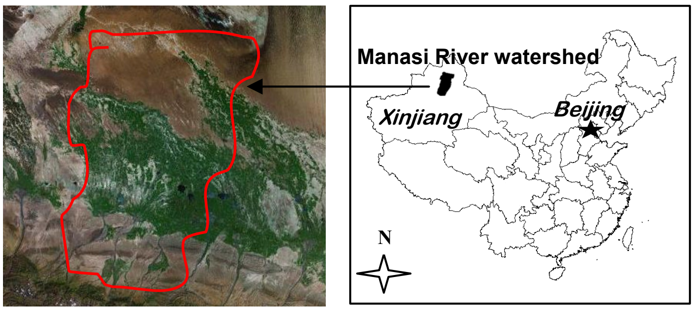

Figure 1. Manasi River watershed sketch map.

Data collection

Three periods of TM, ETM and TM satellite images with 30 m of spatial resolution in 1989, 1999, and 2007 were used to evaluate the dynamics of saline & alkaline soil distribution in Manasi River watershed. Local historical documents concerning farmland area survey were also used as accessorial data. Social, economic and ecological (SEE) developmental data were harvested from local historical documents.

Analysis method

Spatial data are extracted from satellite images over last three decades mentioned above. The landscape analysis program Fragatats 3.3 was employed to analyze the landscape indices, *CA* (Class Area, km^2), *NP* (Number of Patches), and *PAFRAC* (Perimeter-Area Fractal Dimension). *SPLIT* (Splitting Index) was presented to concentrate and scatter characters of land patches.

Results

The evolution of social-economic strategies in preventing the enlargement of saline land over three decades

Manasi watershed's social, economic and environmental (SEE) strategies include economic system, social system and instrumental and engineering system at four levels such as individual farmer, community level, sub-watershed level and whole watershed. In past three decades this area has been the fastest growing among major cities in Xinjiang, with an almost 12% annual increase domestic product (GDP). The instrumental and engineering technique service system in this area has ranged from expertise system, information centre, on-site technical service and community organization (Figure 2). It directly interacted with and served for 115,000 individual farmers in cropping management and fertilizer application including dripping irrigation introduction and soil salt removal and attenuation techniques. Beyond the individual farmer level, local government had conducted a series of soil salt reduction programs including engineering salt-removing system (drainage network to lower the groundwater line by pipe system among over 85% croplands, leakage-preventing trench system and land level-up program throughout all the fields) and biological desalinization projects (salt-washing system by rice cropping and salt-accumulating system by planting trees along with irrigation trenches throughout the watershed) at sub-watershed level. Importantly, all the solutions mentioned rested on a preliminary trial stage and very little was put into practice before 1989, and only till after 1990 had they been developed into a relatively integrated instrumental and engineering technique system. It was since 2000 that overall SEE systems had been built up well, which had coupled interactions with instrumental technique system, including funding input, market system, industrial pattern upgrade, administrative policy, legal insurance system and environmental education (Figure 2).

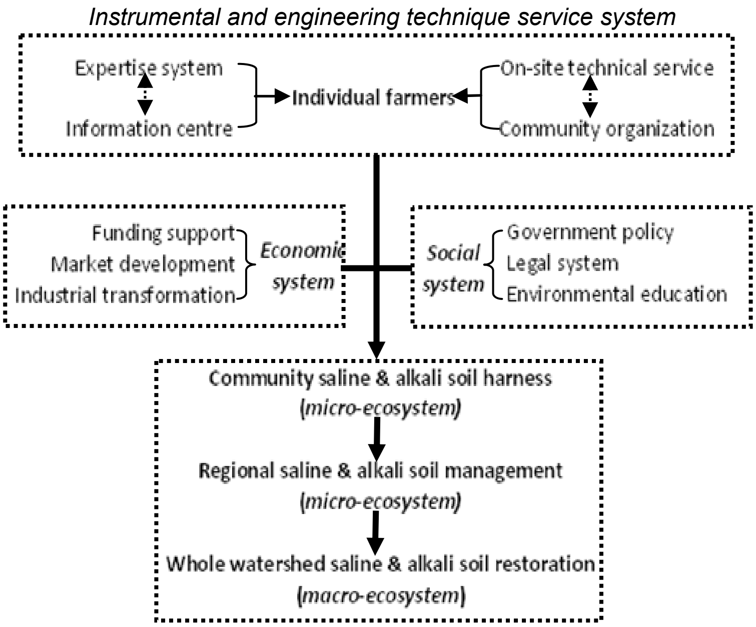

Figure 2. Social, economic & ecological (SEE) system for saline & alkaline soil management at Manasi watershed.

The temporal-spatial dynamics of saline & alkaline soil distribution over three decades

Saline and alkaline soil distribution varied from periods and regions (Figure 3). Total area and patch number were 850.2, 1254.6, 1105.4 km^2 and 116, 129 and 121 in 1989, 2000 and 2007 respectively, showing a dynamics of “first increase and then decrease” trend. However, perimeter-area fractal dimension (PAFD) and splitting index (SI) remained increasing, being up to 1.265, 1.272 and 1.279 for PAFD and 259.29, 269.68, 272.92 for SI in 1989, 2000 and 2007 respectively (Figure 4), suggesting that the spatial pattern of salinized land tended to be shrunk and sequestrated into micro-catchment patches .

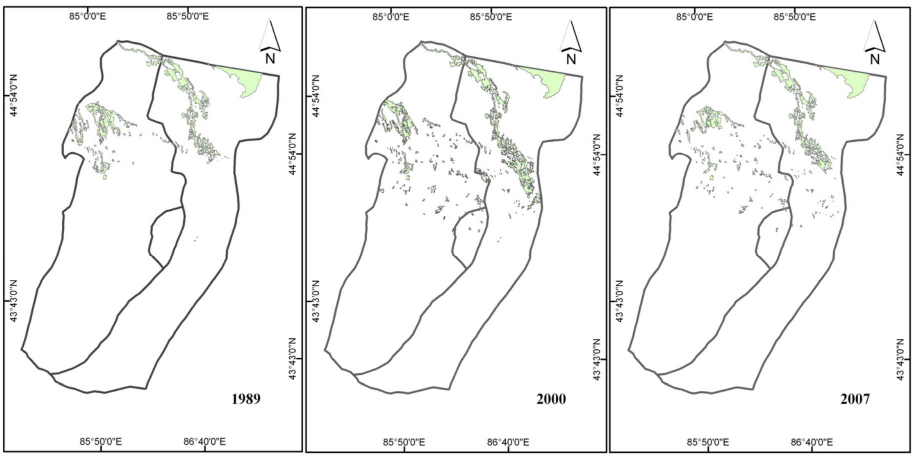

Figure. 3 The temporal & spatial distribution of saline land at Manasi watershed from 1989 to 2007.

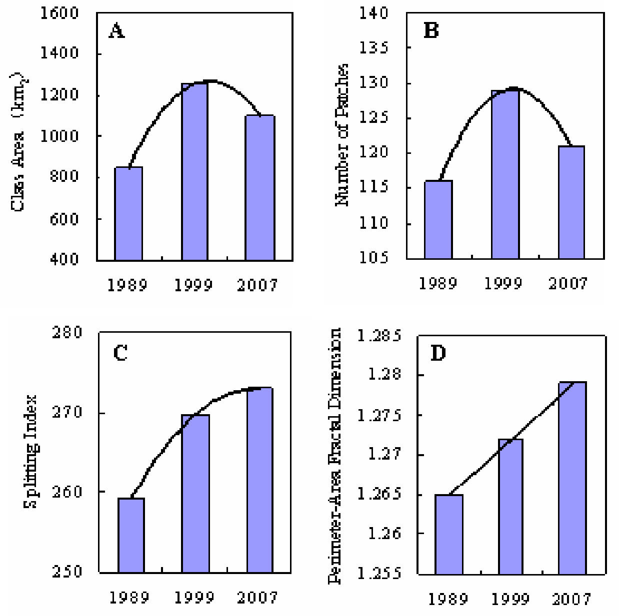

Figure 4. Landscape parameters dynamics of salineland distribution at Manasi watershed from 1989 to 2007.

Conclusion

The lack of SEE harness program will lead to the invalidation of instrumental solutions in practice of saline land control and ecological restoration. Also, the inadequate combination of SEE program into pure instrumental and engineering technique system will let land the salinization crisis get out of control, while the pure technical solution is developed to a "so-called" integrated highly efficient system. Only in fine combination between SEE system and instrumental integrated system is the declamation and utilization of saline and alkaline land able to be gradually sustainable and environment-friendly. Thirty-year lesson from the evolution of saline land at Mansi River watershed provides a promising practical case for other similar areas worldwide. As proposed by Liu *et al.* (2007), coupled human and natural system (CHANS) cannot work well except where the SEE factors are taken into consideration.

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References

Pahl-Wostl C, Mostert E, Tabara D (2008) The Growing Importance of Social Learnning in Water Resources Management and Sustainability Science. *Ecology and Society* **13**, 24.

Jolly ID, McEwan KL, Holland KL (2008) A review of groundwater-surface water interaction in arid/semiarid wetlands and the consequences of salinity for wetland ecology. *Ecohydrology* **1**, 43-58.

Luedeling E, Nagieb M, Wichern F, Brandt M, Deurer M, Buerkert A (2005) Drainage, salt leaching and physico-chemical properties of irrigated man-made terrace soils in a mountain oasis of northern Oman. *Geoderma* **125**, 273-285.

Wals AEJ (2007) 'Social Learning Towards a Sustainable World'. (Wageningen Academic Publishers: The Netherlands).

Weinstein MP (2008) Ecological restoration and estuarine management: placing people in the coastal landscape. *Journal of Applied Ecology* **45**, 296-304.

Liu JG, Dietz T, Carpenter SR, Folke C, Albert M, Redman CL, Schneider SH, Pell AN, Lubchenco J, Taylor WW, Ouyang ZY, Deadman P, Kratz T, Provencher W (2007) Coupled human and natural systems. *Ambio* **36**, 639-648.

Zhu HM (1999) Harness the Saline – alkali soil in Xinjiang. *Journal of Shihezi University (Natural Science)* **3,** Sup. 78-82.

Program of Reclamation and Utilization of Saline and Alkaline soil at Regional Level (2008) 'Local Government Official Program'. (Developmental and Reforming Committee of Xinjiang Bintuan).

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