Assessment of Land Use Functions of Northeast China

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***Abstract*—The ability of land uses providing multiple services is defined as Land Use Functions (LUFs). We divided multifunction of land use into 10 LUFs among the three dimensions of sustainability-social, economic and environmental and assessed the sustainability of land use in Northeast China based on Spatial Regional Reference Framework. Northeast China had both higer sustainability and greater improvement inland use than China's national condition in the 1985-2005 period. Component LUFs showed a trend of being less homogeneous due to unbalanced improvement of land use at regional scale of northeast China. Unbalanced improvement of land use could also be observed at provicial level. As a whole, northeast China faced both the challenges of sustainable land use and the great potential for improvement of LUFs.**

Keywords- land use functions, sustaiability, northeast China

I. INTRODUCTION

Land is a delineable area of the earth's terrestrial surface encompassing all attributes of the biosphere immediately above or below this surface[1] with multifunctionality[2]. Multifunctionality denotes the phenomenon that the landscape actually or potentially provides multiple material and immaterial ''goods'' that satisfy societal needs or meet societal demands by the states, structures or processes of the landscape [3]. The ability of land uses providing multiple services is defined as Land Use Functions (LUFs), a new concept which was drawn within the European project SENSOR with aim to develop ex-ante Sustainability Assessment Tools to support policy making regarding multifunctionalland use in European regions. With the project, LUFs were defined as "the private and public goods and services provided by the different land uses that summarize the most relevant economic, environmental and societal aspects of a region" [4]. And a concept model of Spatial Regional Reference Framework (SRRF) was developed to stratify the European territory into relatively homogeneous regions, integrating biophysical, socio-economic and regional administrative aspects[5]. In this study, land use sustainability of Northeast China was assessed using SRRF. Northeast China, historically known in English as Manchuria, is a geographical region of China, consisting of the three provinces of Liaoning, Jilin and Heilongjiang. Northeast China is today often called the nation's "last fortress of a planned economy" wih a population of near 110 million.

II. FRAMEWORK OF LUFS ASSESSMENT

All aspects of sustainability were meant to be captured when we assessed LUFs. So ten land use functions were considered with each one of them either being societal, economical or environmental[6]. Main societal LUFs included provision of work (LUF1), human health (LUF2)and human homestead(LUF3); main economical LUFs included bioproductive land based production(LUF4), artificial land based production(LUF5) and transport (LUF6); and main environmental LUIFs included provision and maintenance of resources(LUF7), receiver of pollutants(LUF8), landscape and biological culture (LUF9) and maintenance of ecosystem process(LUF10).

The methodological approach of SRRF uesd to assess LUFs is stepwise. In a first step, economic, environmental and social indicators for assessing land use sustainability are collected and the generic nature of the relationship of indicators-LUFs is identified. In our study, 28 key indicators was selected (Table 2). The relationship between indicators and LUFs is multilateral and the nature of relationship between indicators and LUFs using a generic table is to just reflect how each indicator impact some LUFs in a basic ways with no consideration of its differences in spatial pattern and temporal changes. The strength of the significance (namely weight) of each indicator for the LUF is scored using the following weighting scores ranging from -2 to +2:

- 2(strong significance) meaning an indicator enhances/hinders (+/-) LUF in a very significant way;
- 1(medium significance) meaning the indicator enhances/hinders (+/-) LUF but in a limited way;
- 0(irrelevant) meaning the relationship between indicator and LUF isn't allowed to inferred.

The second step regards the identification of the specific regional importance of each indicator for the sustainability. It is well accepted that an indicator may be of different importance in impacting some LUF cross different regions and even in the same region but at different times due to the spatial and temporal disparities of social, economical and environmental situations. Therefore, weighting of different indicators at regional scale (or at different times) is a necessary.

TABLE 2 INDICATORS OF MEASURING LUFS

Dimensions	Indicators
Social	the percentage of people employed in agriculture(%)
	Urban unemployment rate（%）
	Rural Engel coefficient (dimensionless)
	Food self-sufficiency rate（%）
	Green area per urban resident（m^2）
	Population density（cap/ km^2）
	Urbanization rate（%）
Economical	GDP per capita（Yuan）
	Agricultural added value（%, of GDP）
	Grains (equivalent) output（kg/ha）
	Ratio of farming land productivity to its climate potential (dimensionless）
	Agricultural labor Productivity（Yuan/cap）
	Chemical fertilizer applied（t/ha）
	Pesticide and herbicide applied（kg/ha）
	Arable area （mu/cap, 15mu=1 ha）
	Grassland area（mu/cap）
	Livestock products (kg equivalent meat/cap)
	Traffic density（km/km^2）
	Percentage of passenger turnover volume to the national total（%）
	Percentage of cargo turnover volume to the national total(%)
	Water resource（m^3/cap）
Environmental	Rate of industrial wastewater discharges satisfying Discharge Standards （%）
	Emission intensity of COD（t/km^2）
	Carbon footprint(gha/cap）
	Emission intensity of SO_2（t/km^2）
	Nature reserve area（%）
	Forest cover（%）
	soil erosion area（%）

The next step is to define sustainability limits (threshold or similar references) for each indicator and normalize indicator values. Limits for land use sustainability are referred to as a reasonable range in which an indicator could impact on some LUF based on current knowledge about land use sustainability, ranging from least sustainable land use to threshold sustainable and to most sustainable. Using sustainability limits, all indicators wre normalized to the same scale so as to compare the different indicator units, values and impact ways.

And the last step regards to the integrated assessment of LUFs. The value of each LUF is the summary of the multipliers of the regional specific weight of each indicator and its normalized value. And the sum of all component LUF is the aggregated LUF in specific region. The value of land use function, both component and aggregated, may be positive, negative or zero. And the positive value indicates that the defined or aggregated LUF was or is in reasonable use, the negative means in excessive use,and zero value indicate that the negative and positive impacts of indicators on the defined or aggregated LUF exactly counteract as if the LUF were idle. LUFs have theoretical maximum and minimum but both the values are relative at both spatial and temporal scales: the limits might differ at spatial scale and could be improved at temporal scale. So standardized LUF was coined to measure each LUF's distance to its maximum. in our study and defined as the ratio of the dfference between the actual component or aggregated LUF value and its minimum to its conresponding range between the maximum and minimum for a region. Standardized LUF value ranges from 0 (least sustainable)) to 1 (most sustainable).

III. RESULTS OF LUFS ASSESSMENT

During the period 1985-2005, northeast China had more sustaianble land use than China's national conditions.The aggregated sustainability value of LUFs in northeast China was at 56 in 1985, 34% higher than the national average, and at 131 in 2005, 54% higher than the national average. Obviously, northeast China had also faster improvement in land use stainability. In comparison of ten component LUFs (Figure 1), the function of provision and maintenance of resources (LUF7) was most sustainable with the LUF value of 40 in 2005, almost twice of that in 1985. While all the three functions of receiver of pollutants (LUF8), of support and gestation of landscape and biological culture(LUF9) and of maintenance of ecosystem process(LUF10) were negative, indacting they has been in excessive use during the period 1985-2005. The other nine component LUFs but LUF7 was very homogeneous in 1985, but had a trend of being less homogeneous due to unbalanced improvement of land use. Apart that the function of surporting work (LUF1) weakened slightly due to rising urbanization and more farm labors moving to other sectors, all the other LUFs achieved benign improvement in northeast China over the past two decades after 1985.

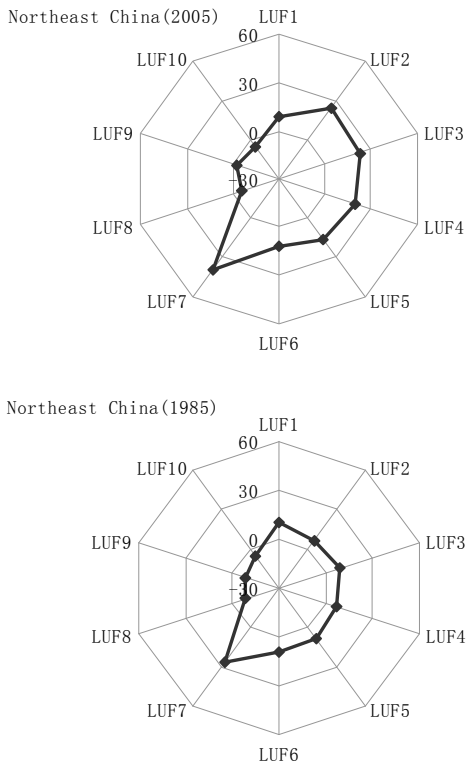

Figure 1. Land use sustainability of northeast China in 1985 and 2005

In the 1985-2005 period, the standardized aggregated LUF in northeast China improved from 0.40 to 0.54 in comparison with the value rising from 0.37 to 0.46 at the national scale of

China. Land had gained reletively higher sustainability in provision and maintenance of resources (LUF7) in 2005, but in the maintenance of ecosystem process(LUF10) in 1985. It indicated that both the private and public goods and services provided by land uses expeirenced ever-growing exploitation which might seriously diminish the prospects for sustainable development. Especially, ecosystem degradation tends to harm rural populations more directly than urban populations and has its most direct and severe impact on poor people[7].

Northeast provincial LUFs of China and their standardized ones are sumarrized in Table 3 and Table 4 respectively. Among northeast China, the relative aggregated LUF of Jilin province was in the lowest in 1985 and rised close to that of Heilongjiang province until 2005. By constract, the aggregated LUF of Liaoning province was intermediate in 1985 while climbed to be the top 1 in 2005. Though doubled during 1985-2005, the aggregated LUF of Heilongjiang province had the smallest improvement among northeast provinces of China. Part of the changes cound be accountd for the lagged transition of Heilongjiang province from a planned, resource-driven economy towards a dynamic market economy. In every northeast China's provinces, both the function of human health (LUF2) and the function of human homestead (LUF3) improved significantly between 1985 and 2005. Ever-rising farming and livestock production output accounted for the most contribution . In recent years, about 33 % of china's total corn output, 38% of beans ourtput, and 20% of beef and milk output came from those provinces. But food security for growing populations will remain a challenge especially under climatic and environmental global change. It had been observed that the impvoing food satisfaction had resulted in negative environmental externalities of ecosystem services degradation as discussed aboved.

Table 3 LUFs of Chinese northeast provinces

LUFS	Standardized LUFs value[a]					
	Liao	Ji	Hei	Liao	Ji	**Hei**
	2005	**2005**	**2005**	**1985**	**1985**	**1985**
LUF1	17.0	5.2	5.4	14.8	7.5	8.7
LUF2	17.5	25.5	29.1	-3.2	9.6	12.9
LUF3	27.8	19.9	18.2	10.4	8.8	9.0
LUF4	21.6	18.6	17.9	14.2	4.9	4.0
LUF5	25.3	13.4	14.0	13.9	4.6	7.3
LUF6	22.4	7.9	5.7	14.2	5.7	6.9
LUF7	25.3	49.2	46.3	17.3	26.8	32.9
LUF8	-9.1	-6.3	-3.5	-10.6	-7.0	-6.4
LUF9	-6.1	-0.6	-0.4	-9.5	-8.2	-7.2
LUF10	-6.0	-5.0	-4.0	-6.0	-5.0	-4.0
Total	135.8	127.8	128.7	55.6	47.6	64.0

[a]Liao=Liaoning Province, Ji= Jilin Province,and Hei=Heilongjiang Province.

As a whole, northeast China gained a growing standardized both aggregated and compoennt LUF in the 1985-2005, indicating that regional land use policies significantly enhanced the land use functions. But the low standardized LUF value implied both the challenges of sustainable land use and the great potential for improvement of LUFs. In response, more adaptive, sound and effective land use policies are needed to be implemented with a new combination of policy tools to improve socio-economic developments.

Table 4 Standardized LUFs of Chinese northeast provinces

LUFS	Standardized LUFs value					
	Liao	Ji	Hei	Liao	Ji	**Hei**
	2005	**2005**	**2005**	**1985**	**1985**	**1985**
LUF1	0.54	0.39	0.40	0.59	0.45	0.40
LUF2	0.49	0.57	0.58	0.23	0.32	0.39
LUF3	0.52	0.37	0.32	0.27	0.19	0.20
LUF4	0.74	0.63	0.61	0.47	0.20	0.17
LUF5	0.62	0.36	0.37	0.46	0.13	0.22
LUF6	0.69	0.25	0.10	0.64	0.10	0.18
LUF7	0.53	0.81	0.75	0.33	0.57	0.56
LUF8	0.31	0.48	0.46	0.21	0.17	0.21
LUF9	0.50	0.57	0.57	0.39	0.43	0.46
LUF10	0.75	0.53	0.55	0.75	0.72	0.68
Total	0.57	0.53	0.52	0.43	0.37	0.39

[a]Liao=Liaoning Province, Ji= Jilin Province,and Hei=Heilongjiang Province.

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