Application of the DPSIR model to analyze ecosystem service drivers of agricultural human-environment systems

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Introduction and research area

The Driver-Pressure-State- Impact-Response (DPSIR) model and ecosystem services assessment are both regarded as important approaches to analyze interacting human-environment systems. Recently, a more complete coupling framework was set up by integrating these two approaches to better analyze human-environment systems (Figure 1)

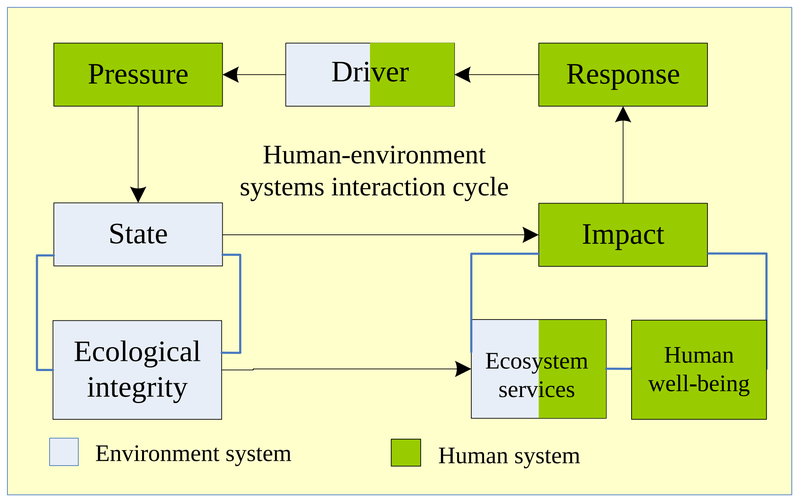

Figure 1. Coupling of DPSIR and ecological integrity/ecosystem services/human well-being in human-environment systems (after Kandziora et al., in review; Haines-Young and Potschin, 2010)

Jiangsu province:

- East of China; composed of 13 prefecture-level cities (see Figure 2)
- most developed region → highly urbanized and industrialized cities in the south
- agricultural productions, rapid increasing industry and increasing population → impact on the local environment
- dominant land cover types: farmland and artificial area

Research aims:

- Quantitatively analyze the drivers of ecological integrity/ecosystem services and human well-being for agricultural human-environment systems with the DPSIR model
- Jiangsu as the case area

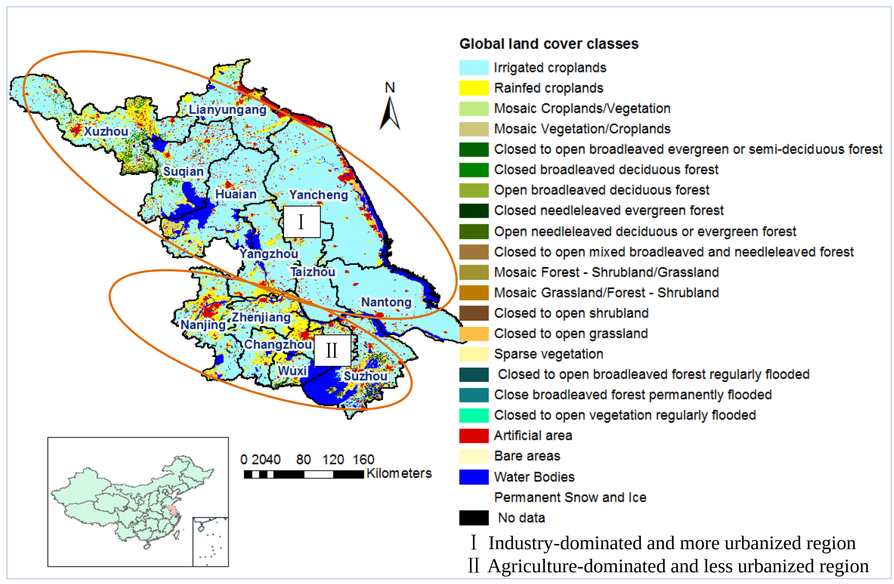

Figure 2. Land cover of Jiangsu's prefecture-level cities in 2006 and zoning according to the urbanization and industrialization level

Data source: Globcover global land cover map of 2006: European Space Agency, Jiangsu prefecture-level cities boundaries map: National Fundamental Geographic Information System (China).
Prefecture-level city is a low level administrative division of province in China, including urban area and rural area.

DPSIR indicators for agricultural human-environment systems of Jiangsu

Based on the characters of Jiangsu's agricultural human-environment systems and the empirical data available, DPSIR indicators are proposed (Table 1). According to the framework of Figure 1, state equals here ecological integrity and impact indicators are divided into ecosystem services sector and human well-being sector.

In order to find out the drivers, a correlation analysis was conducted with each DPSIR indicator, for the 13 prefecture-level cities of Jiangsu,

Table 1. DPSIR indicators for human-environment systems of Jiangsu's prefecture-level cities

Driver	Pressure	State	Impact	Response
✓Total food crops output ✓Population density ✓GDP per person ✓Ratio of gross output value of agriculture to industry	✓Arable land area per capita ✓Proportion of arable land area in total land area ✓Total power of agricultural machinery per unit sown area ✓Level of chemical fertilizer use ✓Level of pesticides use ✓Irrigation rate ✓Acid rain rate	✓Richness of wild higher plant species ✓Richness of wild animal species ✓Diversity of ecosystems ✓Number of endemic species ✓Vegetation coverage index ✓Land degradation index	● Ecosystem services: ✓Food crops output per unit sown area ✓Meat output per unit area ✓Aquatic products output per unit area ● Human well-being: ✓Rural residents' average annual net income ✓Rural residents' average annual expenditure ✓Housing area per person in rural area	✓Government agricultural expenditure per unit sown area of crops ✓Agricultural loans per unit sown area of crops ✓Number of agricultural science and technology personnel ✓Years of rural education ✓The proportion of pollution control investment in GDP

Correlation analysis results

Table 2. Correlations between ecological integrity indicators and driver, pressure and response indicators of Jiangsu' 13 prefecture-level cities for 2006 (only the indicators having significant correlations at the 0.05 level are listed)

Spearman correlation coefficients		Ecological integrity (state) indicators		
		Richness of wild higher plant species	Diversity of ecosystems	Number of endemic species
Driver indicators	Total food crops output	-0,82	-0,63	-0,86
	GDP per person	0,69	0,59	0,81
	Ratio of gross output value of agriculture to industry	-0,70	-0,57	-0,84
Pressure indicators	Arable land area per capita	-0,63	n.s.	-0,68
	Proportion of arable land area in total land area	-0,80	-0,91	-0,70
	Total power of agricultural machinery per unit sown area	0,86	0,78	0,70
	Irrigation rate	0,76	0,64	0,71
Response indicators	Government agricultural expenditure per unit sown area of crops	0,75	0,62	0,88
	Agricultural loans per unit sown area of crops	0,58	n.s.	0,71
	Years of rural education	0,65	n.s.	0,79

Correlation is significant at the 0.05 level; n.s., not significant
Date source: Statistic Bureau of Jiangsu Province, Statistic Bureaus of Jiangsu's prefecture-level cities, College of Economics and Management, Nanjing Agricultural University

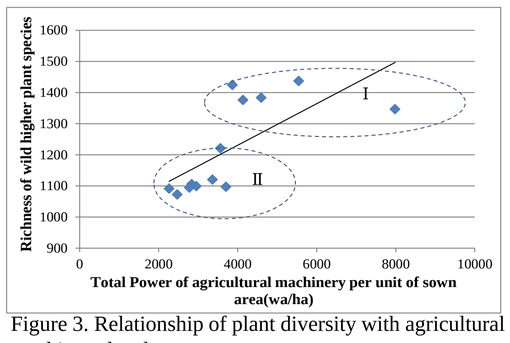

Figure 3. Relationship of plant diversity with agricultural machinery level

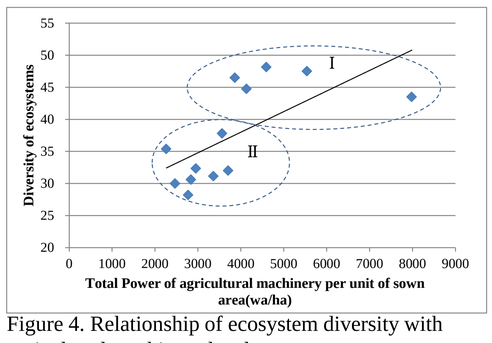

Figure 4. Relationship of ecosystem diversity with agricultural machinery level

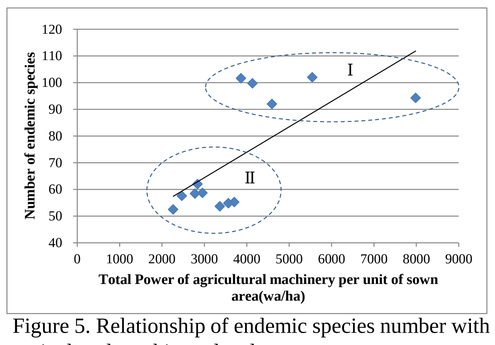

Figure 5. Relationship of endemic species number with agricultural machinery level

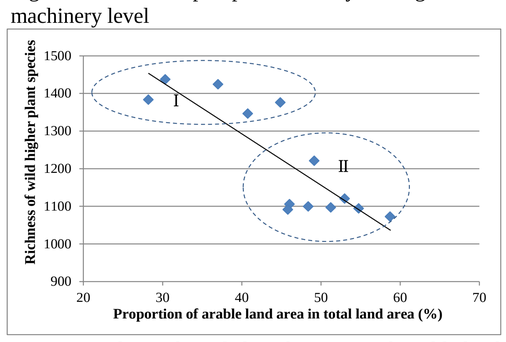

Figure 6. Relationship of plant diversity with arable land proportion

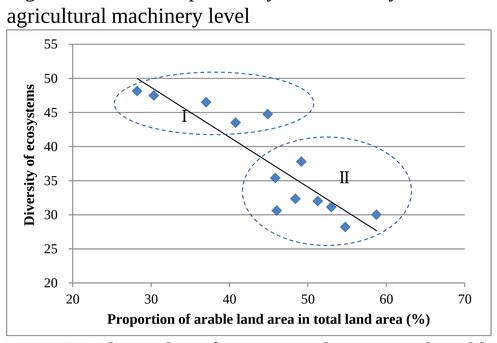

Figure 7. Relationship of ecosystem diversity with arable land proportion

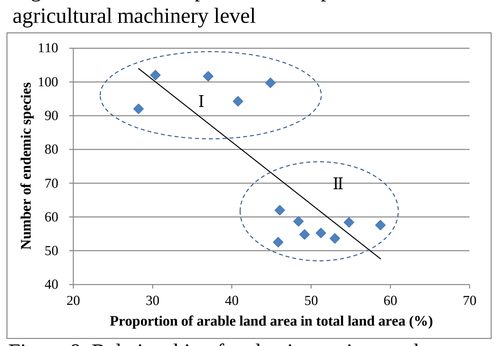

Figure 8. Relationship of endemic species number with arable land proportion

Table 3. Correlations between ecosystem services/human well-being indicators and driver, pressure, state and response indicators of Jiangsu' 13 prefecture-level cities for 2006 (only the indicators having significant correlations at the 0.05 level are listed; n.s., not significant)
Date source: the same as Table 2

Spearman correlation coefficients		Ecosystem services and human well-being (impact) indicators				
		Food crops output per unit sown area	Meat output per unit area	Rural residents' average annual net income	Rural residents' average annual expenditure	Housing area per person in rural area
Driver indicators	Total food crops output	n.s.	n.s.	-0,72	-0,71	-0,63
	population density	n.s.	n.s.	0,59	n.s.	0,65
	GDP per person	0,65	n.s.	0,98	0,97	0,94
	Ratio of gross output value of agriculture to industry	-0,70	n.s.	-0,97	-0,96	-0,92
Pressure indicators	Arable land area per capita	n.s.	n.s.	-0,85	-0,81	-0,86
	Proportion of arable land area in total land area	-0,68	0,62	-0,71	-0,72	-0,58
	Total Power of agricultural machinery per unit sown area	n.s.	-0,68	n.s.	0,57	n.s.
	Level of chemical fertilizer use	n.s.	n.s.	-0,59	-0,63	-0,66
	Irrigation rate	n.s.	n.s.	0,70	0,70	0,63
	Acid rain rate	n.s.	n.s.	0,78	0,74	0,83
State indicators	Richness of wild higher plant species	n.s.	n.s.	0,62	0,59	n.s.
	Diversity of ecosystems	n.s.	-0,68	0,59	0,56	n.s.
	Number of endemic species	0,60	n.s.	0,77	0,77	0,69
Response indicators	Government agricultural expenditure per unit sown area of crops	0,68	n.s.	0,87	0,86	0,82
	Agricultural loans per unit sown area of crops	n.s.	n.s.	0,87	0,83	0,87
	Years of rural education	0,59	n.s.	0,93	0,93	0,89

Table 2:

- The expanding of agriculture has significantly negative impact on local biodiversity.
- The increasing of economic development level, agriculture knowledge and technology level and financial support can obviously benefit the local biodiversity.
- The economic scale and structure are important drivers of the regional biodiversity at the scale of prefecture-level cities in Jiangsu province .

Figure 3 to Figure 8:

- The 13 prefecture-level cities can be divided into two groups.
- Group Ⅰ cities: higher agricultural productivity, less dependence of the economy on agriculture and more biodiversity.
- Group Ⅱ cites: lower farming efficiency, more dependence on agricultural and lower biodiversity.

- Urbanization, industrialization and economic development are the predominant positive drivers of ecosystem food provisioning service and rural residents' well-being at the prefecture-level city scale of Jiangsu.
- The knowledge, technology and finance inputs for agriculture also have generally positive impact on these aspects.
- The expanding of farming land and the increasing of agricultural economy are two important negative drivers of ecosystem food provisioning capacity and local rural residents' living standards.