Energy Analysis for the Sustainability of an Agro-Ecosystem in Ningxia Province, China

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Introduction An important challenge facing China today is the feeding of an increasing population with decreasing energy supplies and finite environmental resources . To meet this challenge the sustainability of agricultural methods must be evaluated to determine how yields can be maximized relative to their resource use and environmental degradation . The Agro-Pastoral Transition Zone of Northern China is an important ecotone (eco-zone ?) . Therefore , the discovery of new tools for sustainable natural resource management in these areas is particularly vital .

Materials and methods The experiment was carried out at Sidunzi County , Yanchi County , Ningxia Hui Autonomous Region , Northwest China (Long 1989) . Sidunzi County is located in the Agro-Pastoral Transition Zone in Northern China . Its agricultural ecosystem contains four sub-system that are cropping sub-system , grassland sub-system and woodland sub-system (Figure 1) . Emergy (spelled with an m) is defined as the available energy of one kind previously used up directly and indirectly to make a product or service (Odum , 1988) . The emergy inputs and outputs , the primary and secondary production condition of the agricultural ecosystem were analyzed with the method of Emergy Theory .

Results and discussion Systemic transformity is used to measure the quality of resource and its position in the universal energy transformation hierarchy . The larger the transformity , the more solar energy required for the production and maintenance of the resource , product or service of interest , and the higher their position in the energy hierarchy of the Agro-ecosystem . From Figure 1 and Table 1 , we can conclude that Grassland sub-system has highest transformity and act as a center function in the Agro-ecosystem . The EYR of the sub-systems ranged from 0 .58 to 3 .02 , which indicated a high level of output per purchased investments . The grassland sub-systems had minimal environmental impacts as shown by ELR 0 .05 . The Emergy Sustainability Index (ESI) of the sub-systems ranged from 0 .5 to 11 , indicating a low level of sustainability .

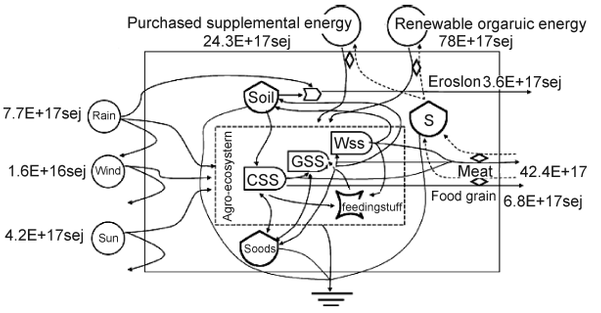

Figure 1 *Systems diagram of the Agro-ecosystem as practiced at Sidunzi County , Yanchi County , Ningxia Hui Autonomous Region , Northwest China . Note : CSS-Cropping sub-system , GSS-Grassland sub-system , WSS-Woodland sub-system .*

Table 1 *Comparison of emergy index (Brown and Ulgiati , 1997) between sub-systems*

Emergy indices	Expression	Agro-ecosystem	Cropping sub-system	Grassland sub-system	Woodland sub-system
Total emergy input($\times10^{17}$Sej)	I	130 .786	28 .44	89 .2745	0 .5844
The output energy of products($\times10^{13}$J)	L	1 .19178	5 .5769	0 .133787	0 .181658
Systemic transformity($\times10^{4}$Sej/J)	I/L	101 .54	5 .10	667 .23	3 .22
Renewable environmental resource($\times10^{17}$Sej)	R	15 .14	1 .29	13 .7	0 .142
unrenewable environmental inputs($\times10^{17}$Sej)	N	3 .56	0 .304	3 .22	0 .0335
Purchased supplemental energy($\times10^{17}$Sej)	F	24 .322	20 .159	1 .365	0 .09244
Renewable organic energy($\times10^{17}$Sej)	T	77 .9856	6 .68762	70 .9817	0 .3162578
The output emergy of products	Y	49 .1816	37 .4997	42 .4105	1 .235
Emergy investment ratio(EIR)	(F+T)/(R+N)	5 .470995	16 .8423	4 .27581	2 .328762
Emergy Yield Ratio (EYR)	Y/(F+T)	0 .480723	1 .396813	0 .586212	3 .021793
Environment Load Ratio (ELR)	(F+N)/(R+T)	0 .299402	2 .565051	0 .054144	0 .274823
Index of sustainability (ESI)	EYR/ELR	1 .60561	0 .544556	10 .82692	10 .9954

Conclusions An emergy-based analysis for the assessment of the sustainability of a typical Agro-ecosystem in Ningxia , China has been performed . The emergy approach employed in this study allowed to consider under the same energetic language natural and anthropic inputs , often mutually excluded by traditional analyses . In the Agro-ecosystem , the grassland sub-system act as a center function . Grassland agroecosystem is a potential method for sustainable resource use and food production . The implementation of regulation of Agro-ecosystem structure to grassland agro-ecosystem , and adjusting the agricultural central production value from farming to livestock breeding are essential strategies required to harmonize agricultural development and ecological protection .