Land Degradation Approach

Methodology and Practice

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1. Abstract

The paper introduces a methodology and practice for land degradation assessment in the semiarid and arid zones along the Great Wall of China, which form a part of the project "Monitoring and Management of Fragile Ecosystems in Shanxi,Shaanxi Inner Mongolia, China, Adb T/A No.1615prc". The study area occupies 8 counties with total area of 43661 km^{-2}, including Maowusu Sand Land, North Part of Loess Plateau, Erdos Sandstone Plateau, Kubuqi Desert and Alluvial Plain of Yellow River. Climate of this area is classified as semiarid to arid temperate with annual mean rainfall of 500 mm to 250 mm. Farming and grazing are the main activities, as well as large scale coal mining in this region. Land degradation as a major kind of environmental degradation, is a pressing problem in the study area. There exist desertification, soil erosion, salinization and vegetation degradation in this fragile marginal land, of which desertification and soil erosion are the key problems. The case study was carried out with integration of RS (Remote Sensing) and GIS data in an ARC/INFO environment. Land Degradation Types, Land Degradation Classes and Rating of Degradation Factors are discussed. Land Type and Land Use were the main mapping units and reinterpreted/ converted into land degradation mapping units. For land degradation studies, both in concept and practice as a method and tool, applied GeoInformation Technology is studied intensively. The core of any land information system should consist of RS, GIS and modeling. With this method the multiple data integration, conversion and extraction are possible to be realized [1].

Key Words: Land Degradation, ReInterpretation, Converting Matrix

2. Methodology of Land Degradation Research

2.1 Detailed Methods For Land Degradation Study

'Land degradation approach' is a land resources study; its systematic study method is described later in the second part. The core of any land information system should consist of RS, GIS and modeling, which can be expressed as following formula:

Spatial data + Statistical data + Attribute data + Modeling

With this method multiple data integration, conversion and extraction are possible [1]. The main procedure of land degradation research is summarized as:

- Comprehensive Land Type Mapping, Land Cover and Vegetation Index Study;
- Land Characteristics Data Base Construction based on Land Type Mapping Units.
- Land Information System (LIS) Construction: Maps are digitized within ARC/INFO, ILWIS or other environment.

- Set up an applied Land Information System: Land Type Units, integrated with land cover and vegetation index, are compared with land degradation classification systems.
- Reinterpretation of Land Type Map into Land Degradation Map: Extraction, Integration and Conversion of the Spatial (polygon etc.) data e.g. for the Land Degradation Map Reproduction.
- Conversion and Reconstruction of Statistic data.
- As the map and land inventory are produced, then sustainable land use planning can be carried on.

The 'land type' is the fundamental element for land degradation study this project, i.e. the Land Type Map will be reinterpreted into Land Degradation Map according to the integration of land cover interpretation from RS and vegetation types and index. Then spatial data transfer or the land degradation map reproduction is based on GIS, such as ARC/INFO or ILWIS system, e.g. the land type mapping units are reregistered with land degradation classification legend. Statistic data transfer or reconstruction is based on the reproduced

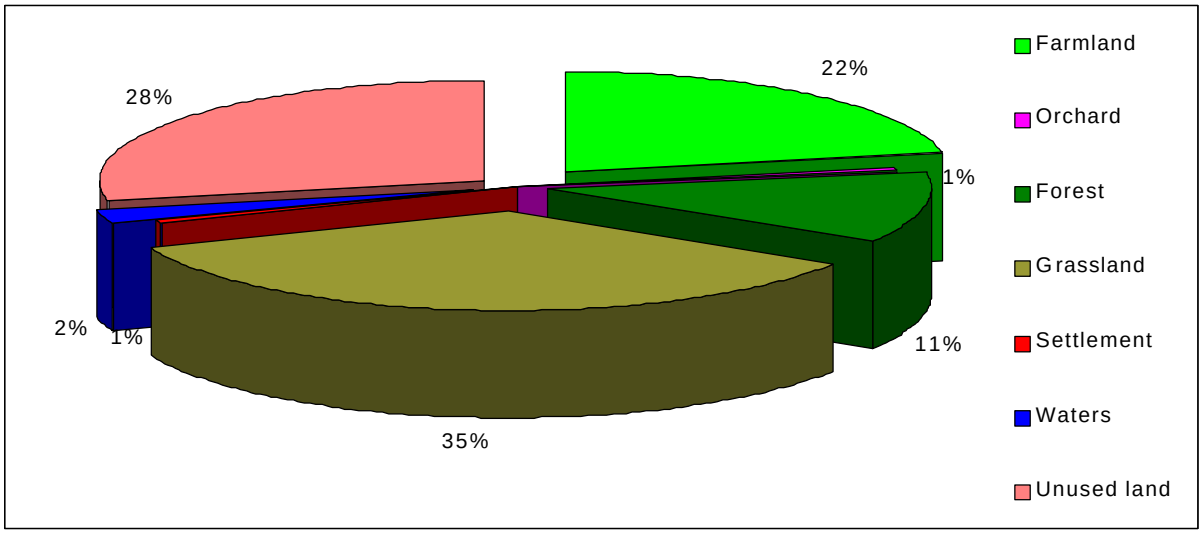

Figure 1. Land Use in the Study Area.

3. Land Degradation Classification Systems

A land degradation classification system must include types, degrees within each type, and degradation units, i.e. three categories of decreasing level are recognized. Generally, land degradation assessment is a kind of land evaluation, and FAO's methodology of land evaluation[2] can be applied.

3.1 Degradation Types

There are four kinds of land degradation recognized: Desertification (D), Soil Erosion (E), Secondary Salinization (S) and Wasted Land (W).
There must also be some transition areas influenced by two or three factors that is remarked with two Letters such as DE, to indicate a transition area as the double phases or multiple phases of degradation. Anyway the simplest is the best, so the key type of degradation is the preferred legend:

Type C1 No degradation	Not/very slightly degraded
Type D Desertification	Land degradation caused by drought, wind erosion, opportunistic farming, over grazing and over cutting in arid or semiarid areas.
Type E Soil Erosion	Land degradation caused by water and wind erosion.
Type S Salinization	Land degradation caused by salinization, including secondary salinity due to poor irrigation management.
Type V Vegetation degradation	Vegetation degraded both in quality and quantity due to over stocking or fuel cutting
Type W Waste land	Land degradation caused by unsuitable use, such as unreclaimed mining sites and polluted areas.

3.2 Degradation Classes

The severity of degradation is indicated by their classes of degradation. The classes are numbered in Arabic numbers, with increasing degrees of degradation within the type, for example, D1, D2, E1, ...,E5 etc.

Class 1 potential degradation, but no evidence or improved.

Class 2 light degradation, mainly vegetation quality degraded so that its utilization value is reduced.

Class 3 moderate degradation, vegetation, and /or soils are influenced.

Class 4 severe degradation, vegetation, soils and landform are strongly influenced so that land use had to be changed from former practice.

Class 5 very severe degradation, land lost its productivity and is very difficult to reclaim.

3.3 Degradation Units

Subdivision of degradation classes, that also are independent mapping units of land types which are distinguished using land degradation criteria and reregistered according to the land degradation legend. They are indicated as land type units, e.g. D1A22, E3H24.

4. Rating of Land Degradation Factors

Land degradation could be identified by its diagnostic factors, which show the causes and/or evidence of land degradation. Land degradation severity is also determined by the rating of its diagnostic factors. Selected factors are chosen and rated: soil erodibility (e); slope degree (p); farming land use (f); vegetation type and vegetation coverage (v) with NDVI [3]. Vegetation cover is rated with attention for local conditions e.g. if rainfall >= 350 mm use the table, if rainfall < 350 mm, the coverage criteria are reduced 10%; salinization (s). All these factors are interpreted with remotely sensed data or field survey data aggregated to land type mapping units and introduced in land evaluation according to FAO[1] . The factors with their ratings are listed hereafter:

Table 1. Slope Degree (p) (potential)

Rating	Slope description	Degree	%
1	flat	< 3	< 5
2	gentle sloping	3 7	5 10
> =3	moderate sloping	7 15	10 25
> =4	strong sloping	15 25	25 45
> =5	steep sloping	25 35	45 60
> 5	very steep	> 35	> 60

Table 2. Erosion Resistance (e)

Rating	Slope (%)	Slope length (m)	Vegetation cover (%)	Land use (farmland)
1 none	< 5	0 12	>90	flat terrace
2 light	5 10	12 30	70 90	high terrace
3 moderate	10 25	30 60	50 70	gentle sloping
4 severe	25 45	60 150	30 50	moderate sloping
5 very severe	45 60	> 150	10 30	steep sloping
6 extremely severe	> 60	> 150	< 10	very steep sloping

Table 3. Farmland Use (f) (interpretation marks)

Rating	Land Use
1	flat alluvial lowland or terraced farmland
2	very gentle sloping or terraced farmland
3	gentle sloping dryland in loess hills
4	moderate sloping dryland in loess hills, cultivated flat sand land and overstocking.
5	steep sloping dryland in loess hills, opportunistic farming in sand desert and over cutting.

Table 4. Vegetation Type and Coverage (v) (interpretation marks)

Rating	Vegetation type	Coverage %	NDVI $\frac{TM4-TM3}{TM4+TM3}$	Ecological review(zones)
1	forest	>80	?	?
1	bushes & grasses	>80	?	?
2	bushes & grasses	60 - 80	?	?
3	bushes & grasses	50 - 60	?	?
4	bushes & grasses	30 - 50	?	?
5	bushes & grasses	15 - 30	?	?
6	semibush	<15	?	?

Table 5. Salinity (s)

Rating	Influence	Remarks
1	none or very slight	no harm, well drained
2	slight	slight harm, seasonally influenced
3	moderate	strong infl. to crops, water logging
4	severe	unsuitable for crop, salt white spots
5	very severe	rare vegetation cover with large part of bare land and salt white spots

5. Land Type Mapping Units

Depending on the data available to the GIS system, the land degradation map could be produced by converting the land type map of 1: 100 000. This was sometimes problematic because the map scale was too small. It is then possible to use data of the project of Loess Plateau Remote Sensing project at the scale 1: 50 000, so that land degradation mapping could still be done with proper accuracy. The description [1] for land type mapping at 1: 100000 (marked with numbers) is contiguous with the units used at 1:50 000 scale that are listed in tables 6 and 7.

6. Land Type Map Re-Interpretation Into a Land Degradation Map

6.1 General Procedure

Land degradation should be expressed by its identification: land type mapping units and their land characteristics are to be referred by the land degradation factors and ratings: Land Type Mapping Units.

(1) DIFR (Degradation Identification Factors and Ratings):

- e ? Re ? (soil erodible and its rating)
- p ? Rp ? (slope and its rating)
- f ? Rf ? (farmland use and its rating)
- v ? Rv ? (vegetation type, coverage and its rating)
- s ? Rs ? (salinization and its rating)

(2) The factor of highest rating and class:

The degradation class following the highest factor rating;

- Class 1 the highest factor rating = or < 1
- Class 2 the highest factor rating = or < 2
- Class 3 the highest factor rating = or < 3
- Class 4 the highest factor rating = or < 4
- Class 5 the highest factor rating = or > 5

(3) The degradation type:

- C ? (no degradation)
- D ? (desertification)
- E ? (soil erosion)
- S ? (salinization)
- V ? (vegetation degradation)
- W ? (waste land)

Class 1 has no specified degradation type.

D, E, S, W all are included in V, so V will be chosen last to identify land degradation.

6.2 Converting Land Type Units to a Land Degradation Map

The land type mapping unit is defined by its land characteristics. Professor Beek gave the idea of Soil Survey Interpretation for Land Evaluation [4], [1] and practiced land type map reinterpretation into land evaluation [3], A Conversion Matrix of land types into land degradation classes is in table 6. Land Types were mapped with infra-red airphoto and TM images, land characteristics were recorded during field survey or inferred from the soil map. Expert comment was sometimes. Finally, each land type mapping unit will be matched with a land degradation legend. A set of tables is given to present the criteria and research results.

7. Conclusions

GeoInformation Technology is a powerful tool for land assessment. The strength comes from cooperation of RSGIS Experts and Land Specialists. Land degradation approach is a kind of land evaluation, field work, RS and GIS data, and other data resources can be integrated to identify the land type with its properties and than the state of its degradation, and countermeasures could be taken by decision makers for land sustainable use.

Table 6. Converting land types into land degradation units

Land Type	Degradation factors & ratings						
	p	e	s	f	v	comment	degradation
A River Valley Alluvial, >250 m wide with constant waters							
A1 flooding land and lowland							
A12 grasses & bush	1	1	2		2	?	V2A12
A15 rice field	1	1	2	1			C1A15
A2 terraces							
A21 irr. Farmland	1	1	1	1			C1A21
A22 dry farmland	1	1	1	1			C1A22
A23 orchard	1	1	1	1			C1A23
A24 woodland	1	1	1		1	?	C1A24
A25 grasses & bush	1	1	1		3	?	V3A25
A26 saline soils	1	1	34		3	?	S3A26
H Loess Plateau, dissected rolling hills and gully.							
H1 interfluvial highland & sloping hills							
H11 gentle sloping farm land	3	3	1	3			E3H11
H12 moderate sloping farm land	4	4	1	4			E4H12
H13 steep sloping farm .land	5	6	1	5			E5H13
H14 terraced farm land	1	2	1	2			E2H14
H15 woodland	35	23	1		2	?	E2H15
H16 grasses & bush	35	4	1		34	?	E4H16
H17 bare soils	5	6	1		5		E5H17
H18 sand cover	5	7	1		5		E5H18
H19 rock outcrop	6	6	1		5		E5H19

Table 7. Land types with their limitations and ratings as applied in the project area

Definition	Pixels	% of total	Limitation & rating								
Alluvial Rivers	**841812**	**section amount 4.83**	**p**	**e**	**d**	**t**	**f**	**l**	**s**	**m**	**a**
01 river lowland	273871	1.57	1	1	d2	t3	f2	1	s2	1	a3
02 river terraces	493137	2.83	1	1	1	1	1	1	1	1	1
03 high terraces	74804	0.43	p2	e2	1	1	2	2	1	m2	a2
Alluvial Fan	**427132**	**section amount 2.45**									
11 cultivated	266265	1.53	1	1	1	1	1	1	1	1	1
12 woodland	13728	0.08	1	1	1	1	1	1	1	1	1
13 bushgrasses	128464	0.74	1	1	1	t2	1	1	s2	1	1
14 bare land	9710	0.06	1	1	1	t2	f5	1	4	1	1
15 saline soils	8965	0.05	1	1	1	1	1	1	3	1	1
Interfluvial Loess Hill	**2300850**	**section amount 13.20**									
21 cultivated	1692897	9.71	p3	e3	1	1	f4	i4	1	m3	a3
22 woodland	42400	0.24	p4	e3	1	1	f3	i4	1	m4	a4
23 bushgrasses	437058	2.51	p4	e4	1	1	f3	i4	1	m4	a4
24 bare land	25227	0.14	p5	e6	d5	1	f4	i4	1	m5	a4
25 sand cover	103268	0.59	p5	e6	1	t4	f4	i4	1	m5	a4
Loess Valley Sideslope	**2716384**	**section amount 15.58**									
31 cultivated	55870	0.32	p4	e4	1	1	f3	i4	1	m4	a4
32 woodland	89204	0.51	p5	e3	1	1	f2	i4	1	m4	a4
33 bushgrasses	1617191	9.27	p5	e4	1	1	f3	i4	1	m4	a4
34 wasted grasses	649689	3.73	p5	e5	1	1	f3	i4	1	m4	a4
35 land slides	12299	0.07	p3	e3	1	1	f3	i4	1	m3	a3
36 earthed old valley	26345	0.15	p3	e3	1	1	f2	i4	1	m3	a2
37 rock outcrop	265786	1.52	p6	e6	d4	t3	f3	i4	1	m4	a4

Definition	Pixels	% of total	Limitation & rating								
Valley Bed of Loess Area	**110365**	**section amount 0.63**									
43 woodland	1811	0.01	p2	e2	1	1	f2	i3	1	m2	a2
46 cultivated	108554	0.62	1	1	1	1	1	i2	1	1	a2
Sandstone Hill	**574312**	**section amount 3.29**									
51 interfluvial	253540	1.45	p4	e4	d3	t2	f3	i4	1	m4	a4
52 sideslope	320772	1.84	p5	e5	d4	t3	f4	i4	1	m4	a4
Limestone Hill	**5818**	**section amount 0.03**									
61 interfluvial	5756	0.03	p4	e4	d3	t2	f3	i4	1	m4	a4
62 sideslope	62	0.00	p5	e5	d4	t3	f3	i4	1	m4	a4
Sands	**9229536**	**section amount 52.93**									
81 shifting dune	1435649	8.23	p3	e5	1	t4	f5	i4	1	m5	a5
82 semifixed dune	994029	5.70	p3	e4	1	t4	f4	i4	1	m5	a4
83 fixed dune	1083071	6.21	p3	e3	1	t4	f3	i4	1	m5	a3
84 bare flat sand	820304	4.70	p2	e3	1	t4	f4	i4	1	m5	a3
85 bushgrass flat sand	1484524	8.51	p2	e2	1	t4	f3	i4	1	m5	a3
86 woodland	252606	1.45	p3	e2	1	t4	f3	i4	1	m5	a3
87 elongated hill	1983254	11.37	p4	e4	1	t4	f4	i4	1	m5	a4
88 cultivated flat sand	315076	1.81	p2	e3	1	t4	f4	i4	1	m5	a4
89 valley bed	861023	4.94	p2	1	1	t3	f3	i2	1	1	a2
Wetland in Sand Areas	**978833**	**section amount 5.61**									
91 cultivated wetland	304660	1.75	1	1	1	1	1	1	s2	1	1
92 meadow	632748	3.63	1	1	1	1	1	1	s2	1	1
93 saline soils	21958	0.13	1	1	1	1	f2	1	s4	1	1
94 lake fringe	19467	0.11	1	1	1	1	f2	1	s3	1	1
Water Surface	**228607**	**section amount 1.31**									
95 river	170623	0.98									
96 lake	46307	0.27									
97 reservoir	5969	0.03									
98 pond	5708	0.03									
99 undifferentiated	23111	0.13									
Total	**17436760**	**100.00**									

Table 8. The total areas of limitation types in the project area.

Limitations	p	E	d	t	f	i	s	m	a
% of total	85.47	80.53	6.55	60.73	87.34	52.93	8.03	80.53	87.66

Table 9. Land degradation analysis based on land types of the project area.

Definition	Pixels	% of total area	Land Degradation remark					
			C	D	E	S	V	W
Rivers	**841812**	**section amount 4.83**						
01 river lowland	273871	1.57	C1					
02 river terraces	493137	2.83	C1					
03 high terraces	74804	0.43	C1					
Alluvial Fan	**427132**	**section amount 2.45**						
11 cultivated	266265	1.53	C1					
12 woodland	13728	0.08	C1					

Definition	Pixels	% of total area	Land Degradation remark					
			C	D	E	S	V	W
13 bushgrasses	128464	0.74					V2	
14 bare land	9710	0.06				S5		
15 saline soils	8965	0.05				S3		
Interfluvial Loess Hill	**2300850**	**section amount 13.20**						
21 cultivated	1692897	9.71			E34			
22 woodland	42400	0.24					V2	
23 bushgrasses	437058	2.51			E34			
24 bare land	25227	0.14			E5			
25 sand cover	103268	0.59		D5				
Loess Valley Sideslope	**2716384**	**section amount 15.58**						
31 cultivated	55870	0.32			E4			
32 woodland	89204	0.51					V2	
33 bushgrasses	1617191	9.27			E4			
34 wasted grasses	649689	3.73			E5			
35 land slides	12299	0.07			E3			
36 earthed old valley	26345	0.15			E3			
37 rock outcrop	265786	1.52			E5			
Valley Bed of Loess Area	**110365**	**section amount 0.63**						
43 woodland	1811	0.01	C1					
46 cultivated	108554	0.62	C1					
Sandstone Hill	**574312**	**section amount 3.29**						
51 interfluvial	253540	1.45			E4			
52 sideslope	320772	1.84			E5			
Limestone Hill	**5818**	**section amount 0.03**						
61 interfluvial	5756	0.03			E4			
62 sideslope	62	0.00			E5			
Sands	**9229536**	**section amount 52.93**						
81 shifting dune	1435649	8.23		D5				
82 semifixed dune	994029	5.70		D5				
83 fixed dune	1083071	6.21	C1					
84 bare flat sand	820304	4.70		D5				
85 bushgrass flat sand	1484524	8.51		D3				
86 woodland	252606	1.45	C1					
87 elongated hill	1983254	11.37		D4				
88 cultivated flat sand	315076	1.81		D4				
89 valley bed	861023	4.94	C1					
Wetland in Sand Areas	**978833**	**section amount 5.61**						
91 cultivated wetland	304660	1.75	C1					
92 meadow	632748	3.63				S3		
93 saline soils	21958	0.13				S4		
94 lake fringe	19467	0.11				S3		
Water Surface	**228607**	**section amount 1.31**						
95 river	170623	0.98						
96 lake	46307	0.27						
97 reservoir	5969	0.03						
98 pond	5708	0.03						
99 undifferentiated	23111	0.13						
Total	**17436760**	**100.00**						

Table 10. Land degradation types.

Degradation types	C	D	E	S	V	W
% of total area	21.42	40.91	30.75	3.98	1.49	?

Table 11. Land degradation analysis based on land use of the project area.

LU Definition	Pixels	% of total area	Land Degradation remarks					
			C	D	E	V	S	W
Farming Land	**3814101**	**section amount 21.90**						
11 paddy field	21241	0.12	C1					
12 irrigated farmland	802538	4.61	C1					
13 rainfed farmland	2990322	17.17		D	E			
Orchard and Garden	**8661**	**section amount 0.05**						
21 orchard	8307	0.04	C1					
22 gardens	35	0.00	C1					
Forest	**1980492**	**section amount 11.37**						
31 trees	215716	1.24	C1					
32 bushes	1516404	8.71					V	
33 open woodland	248372	1.43					V	
Grassland	**6138758**	**section amount 35.24**						
41 natural	5177898	29.73		D	E			
42 artificial	960860	5.52	C1					
Residential & Industrial	**31133**	**section amount 0.18**						
51 city & town	6796	0.04						
52 village	22959	0.13						
53 industrial	1340	0.00						
64 shipping port	38	0.00						
Water Surface	**507699**	**section amount 2.91**						
71 river	144693	0.83						
72 lake	48217	0.28						
73 reservoir	11967	0.07						
74 pond	5261	0.03						
75 fishery pond	5080	0.03						
76 river bed	292481	1.68						
Unused Land	**4936614**	**section amount 28.34**						
81 wasted grassland	1904101	10.93			E			
82 saline soils	33572	0.19				S		
83 marshes	8169	0.05					V	
84 sand	2514929	14.44		D				
85 bare land	49949	0.29			E			
86 rock outcrop	413742	2.38			E			
87 the rest land	54	0.00						W
99 undifferentiated	12098	0.07						
Total	**17417458**	**100.00**						

Table 12. Land degradation assessment based on land use (roughly).

Land degradation types	C1	D	E	S	v	W
% of total area	11.54+	61.34	60.50	0.69+	10.19+	?

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