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Do Farmers' Asset Values Correlate with Land Quality?

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Abstract

This paper investigates if farmers' asset values have a predictive power to asses land quality. A rich sustainable livelihood literature describes small farmers' biophysical and socio-economic environment through asset values, which closely adheres to the required information for an integrated quality appraisal of the natural resource base. For our analysis we use an in-depth survey held among 50 famers' households in three rural areas of Senegal. Farmers gave scores for their livelihood assets (human, physical, natural, financial and social) and judgments on the state and trend of the quality of their natural resource base (crop land, rangeland, forest and water resources). As our observational data are dominated by unobserved heterogeneity, we refrain from causal statistical analysis and seek associative patterns between asset values and state and trend of natural resource quality using data visualization techniques and descriptive statistics. We compare categorical data on state and trend of land qualities with asset value classes in a frequency distributions evaluation (Chi-square) and with continuous asset value scores in an analysis of variance (ANOVA). For state of forest we found consistent but counterintuitive differences for various asset values with higher asset values for 'degraded' classes and lower values for 'good' quality of the forests. There is some evidence that trend of forest quality can be derived from asset value scores which were in agreement with our premise of lower scores for low quality and higher scores for better quality. Yet, overall we have to conclude that asset values do not correlate straightforward and unequivocally with state and trend of natural resource quality.

Keywords: Senegal, natural resource quality, asset value, farmers

1. Introduction

Degradation of the natural resource base constitutes a serious impediment to meet the increasing demand for food commodities of a mounting and more affluent global population. Especially farmers in development countries with restricted access to capital and inputs to compensate detrimental land degradation effects are hit hard by a decreasing productivity of the natural resource base (Pingali, Schneider & Zurek, 2014).

Senegal is a particular point in case. Sonneveld, Keyzer, Zikhali & Merbis (2010) (Note 1) showed that 34 per cent of the national territory and 58 per cent of the agricultural area is affected by land degradation and now seriously impairs the quality of eco-system services and food production. The same study showed that an additional 26 per cent of the total land area and 40 per cent of the agricultural area faces an expansion of the degradation. With a staggering population growth of 2.9 per cent in the period 2010-2015 (UNData, accessed 2014) and a prevailing 19 per cent of chronic malnutrition under children (DHS, 2013), Senegal is confronted with a huge challenge to secure the food production for its future population and protect the long-term productive capacity of its natural resource base.

The Senegalese government has recognized the severity of these problems (Declaration of Abuja; IFDC, 2006; Senegal Emergent Plan; ADB, 2014) and the calls for a warning system that timely identifies conditions under which land degradation occurs are, therefore, justified and demands a proper follow-up from the research community. Yet, planning of policy interventions seems to be constrained by a clear identification of conditions and land user profiles that can be related to the hazard of natural resource degradation. Profiling of potential victims of degradation processes is also the main incentive to shift the research from biophysically process-based models (e.g. Quine et al., 1997; Hairsine and Rose, 1992; Gamvroudisa, Nikolaidisa, Tzorakib, Papadoulakisc, Karalemasc, 2015) that follow physical flows of degradation in detail to a more integrated analysis that includes biophysical as well as socio-economic and institutional conditions (e.g. Vu, Frossard, Vlek, 2014; Nkonya and Weston, 2015). There are basically two reasons for this. First, physically based models designed in a laboratory and in small field plots could not cope with the variability of field conditions at larger scales that are required for policy making at the higher levels (Nearing and Hairsine 2011). Hence, these models required a strong site specific calibration program and local expert knowledge of the terrain which, of course, excludes their universal use in places that could not be visited (Breshears, Whicker, Johansen, & Pinder, 2003). A second reason is that degradation of natural resources is by definition evoked by an interaction between environmental conditions and human behavior. Hence, causal relationships that are relevant for defining land conservation policies require knowledge of the biophysical environment as well as of land users and related institutions that require coordinated activities beyond the individual level. Hence, most analytical studies on natural resource degradation follow integrated statistical approaches where information collected on natural environmental factors and socio-economic conditions of custodians are used to identify the significance of causal relationships or associative patterns that can explain the state of land quality (e.g. Pender, Nkonya, Jagger, Sserunkuuma, & Ssali, 2004; Firew, 2014).

This paper follows the latter approach and seeks the possibility to relate asset values derived from the sustainable livelihood approach (Chambers and Conway, 1992; Scoones, 1998) to the hazard of natural resource degradation. Using approaches described in Carney (1998) this study adopts the use of five asset values that are essential for the pursuit of livelihood strategies that are related to land quality:

- Natural capital. Natural resource stocks and environmental services.
- Financial capital. Capital base, access to credit.
- Human capital. Skills, knowledge, ability to labor and physical capability.
- Social capital. Resources for coordinated actions.
- Physical capital. Basic infrastructure and production equipment.

These asset values provide a comprehensive dynamic overview of farming systems, monitor development and changes in their levels over time (e.g. Chen, et al., 2013; Katerberg et al., 2012) so as to identify timely the constraints for sustainable development and express the concerns over employment, poverty reduction, security, well-being and capability as well as quality of the natural resource base.

We will confront the value of these assets with qualitative assessments on the state and trends in degradation for various natural resources that are managed by the rural population in Senegal. Specifically, farmers were asked to value assets with a score between 0 (low) and 10 (high) and indicate for four natural resources (crop land, rangeland, forest and water) the quality of their current state as 'low', 'moderate' and 'high' and the quality of changes over time (trend) as 'rapidly decreasing', 'decreasing', 'stable', 'improving' and 'rapidly improving'. For our study we use data that were collected under the FAO/UNEP sponsored Land Degradation in Dryland Areas (LADA) project. Guidelines on the Local Level Assessment of Land Degradation and Sustainable Land Management were provided by Bunning, McDonagh, Rioux, & Woodfine, 2011. With this study we aim to support decision makers into prioritizing policy interventions that target specific assets so as to improve the quality and productivity of the natural resource base.

The paper proceeds as follows. Section 2 describes data and methodology used in this study. Section 3 discusses the relation between asset values and rate and state of resource quality for crop land, rangeland, forest and water resources. Section 4 concludes.

2. Data and Methods

A team of field experts conducted a detailed local assessment on natural resource quality and asset values. The assessment consisted of focus group discussions at village level, household surveys among farmer families and a soil and vegetation inventory. The methodologies for these local assessments are described in (Mcdonagh et al., 2010). Here we present a brief summary of the guiding principles for this data collection exercise and its application in Senegal.

2.1 Sampling Strategy

Three Geographic Assessment Areas (Note 2) (GAA) were selected that were representative for major land uses, biophysical variability and degree of natural resource degradation in Senegal. Based on interviews and reconnaissance surveys one to three transects were defined that followed the diversity of prevailing biophysical and land use characteristics in the GAAs. Along these transects two to three representative study areas were selected where one to four representative villages where visited for focus group discussion with key informants of the community (one per village) and household surveys (four to six per village). The distribution of the selection of households over the wealth classes (poor, medium, better-off) followed the prevailing wealth distribution of the village population. Descriptive narratives of selected GAAs, transects, study areas, villages and sites are found in the reports CSE (2009a-e), a short description of the three GAAs is given below.

Niayes **i**s a coastal area with rainfall varying from 300 - 400 mm per annum concentrated in the months of August and September. 'Living' white dunes near the coast are followed by semi-fixed yellow dunes more inland. Humid depressions with fertile soils ('niayes') are a regular occurrence. At the boundary of these depressions typically oil palm and coconut are found. Main land use is horticulture in the 'niayes', but livestock and forestry are also a source of income.

Nioro du Rip has a mean annual rainfall of about 700 mm. Approximately 85% of the rainfall occurs in the months July, August and September. Terrain is relatively flat and soils vary in fertility levels. Main land use type is rainfed agriculture with groundnuts, millet, maize and sorghum as crops. Where water availability permits, horticulture is also practiced. Second most important land use is rearing of livestock in a sedentary extensive manner.

Zone sylvopastoral is located in the North of Senegal with mean annual rainfall of about 400 mm, 90 per cent of which falls in July, August and September. Soils are mainly formed in sedimentary formations with flat topography and varying in texture from sandy to clayey. The main activity is keeping livestock in an extensive manner; in the rainy season there is some arable farming. Some forestry activities are conducted like collection of fruit, fuel wood, timber and pole wood. In total 50 households were interviewed. The number of households and their location within each GAA is presented in

Table 1.

Table 1. Number of households by GAA, transect and village

GAA	Transect	Village	Number of farmers
Niayes	Lompoul-Thioucougne	Lompoul sur Mer	4
	Mabouye-Khonkh Yoye	Mabouye	3
		khonkh_yoye	3
Nioro_du_Rip	Keur-Yoro-Khoudia	Goria	4
		Keur Massamba Codou	3
		Thiambène Walo	4
	Saboya	Keur Tapha-Koutango	4
		Keur_Amady_Nguenar	3
		Thiwalo-Keur Aly Mbath	4
Zone_sylvopast	Diabal-Niakha	Diabal	3
		Niakha	3
	Diagaly-A3	Diagaly	6
	Touba_NF_A3	Katma	2
		Touba_Ndar_Fall	4

2.2 Survey Data

The survey collected information on a wide inventory of various subjects related to natural resource quality, socio-economic conditions of the household, and the institutional environment that are described in McDonagh et al. (2010). Here we concentrate on the information that was collected by the farmers on asset values and state and trend of natural resource degradation. Concerning asset values, farmers were asked to give a score (in the range of 0-10) for each of the five assets taking into consideration the topics that are listed in

Furthermore, each farmer was asked to indicate the quality and trends of land degradation for crop land areas, rangeland, forests and water sources with the descriptive terms that are presented in

Table 3 and Table 4, respectively

2.3 *Statistical Analysis*

We practice two descriptive statistical techniques. First, Pearson's Chi-square tests the null hypothesis whether paired observations of categorical asset classes and qualitative state and trend of land quality classes are independent of each other, which means that distribution of data is due to chance and asset value classes will have no relation to state and trend of natural resource degradation. We, therefore, report on expected distribution under the null hypothesis so as to assess if patterns deviate significantly from observed values. The expected value within each cell is the product of row total and column total divided by overall sample (Preacher, 2001). Second, we test the variability between group means of asset value scores and compare these with results that are expected from chance alone. Our unbalanced observations for the qualitative state and trend of land quality assessment demands the use of a Generalized Linear Model (GLM) approach which takes into account the size of the data set to assess variance as a measure of variability. The ratio of the asset value mean square and the error mean square (deviations of data around the group means) is the well-known F-ratio. The F distribution represents the range and likelihood of all possible *F-ratios* under the null hypothesis (i.e. asset values are identical for all land quality classes). The threshold probability was set at 0.1 and 0.05.

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Table 2. Topics considered for asset scoring

Asset	Topic
Physical	Farm equipment Type of traction Motorcycle
Financial	Microcredit Agricultural Income Income derived from rearing Other income sources
Natural	Number of livestock

	Farm size Land quality Quality of drinking water (for animals) Quality of Grazing land
Human	Education Household size Number of workers Know-how Technical support Membership of organization Access to land
Social	Kinship network Food safety Access to markets Access to health care Access to school Access to drinking water

Table 3. Class categories on quality of natural resources

Code	Category
1	good
2	Moderate
3	Low/degraded

Table 4. Class categories trend in resource degradation

Code	Category
1	improving fast
2	Improving
3	Stable
4	Decreasing
5	rapidly decreasing

3. Results

We start our analysis of household surveys by analyzing the distribution of scores for: social, human, natural, financial and physical assets in each of the three GAAs. Next, we report on state and trends in land quality for natural resources: crop land, rangeland, forest and water. Finally, we combine the asset with information on state and trend of natural resource quality.

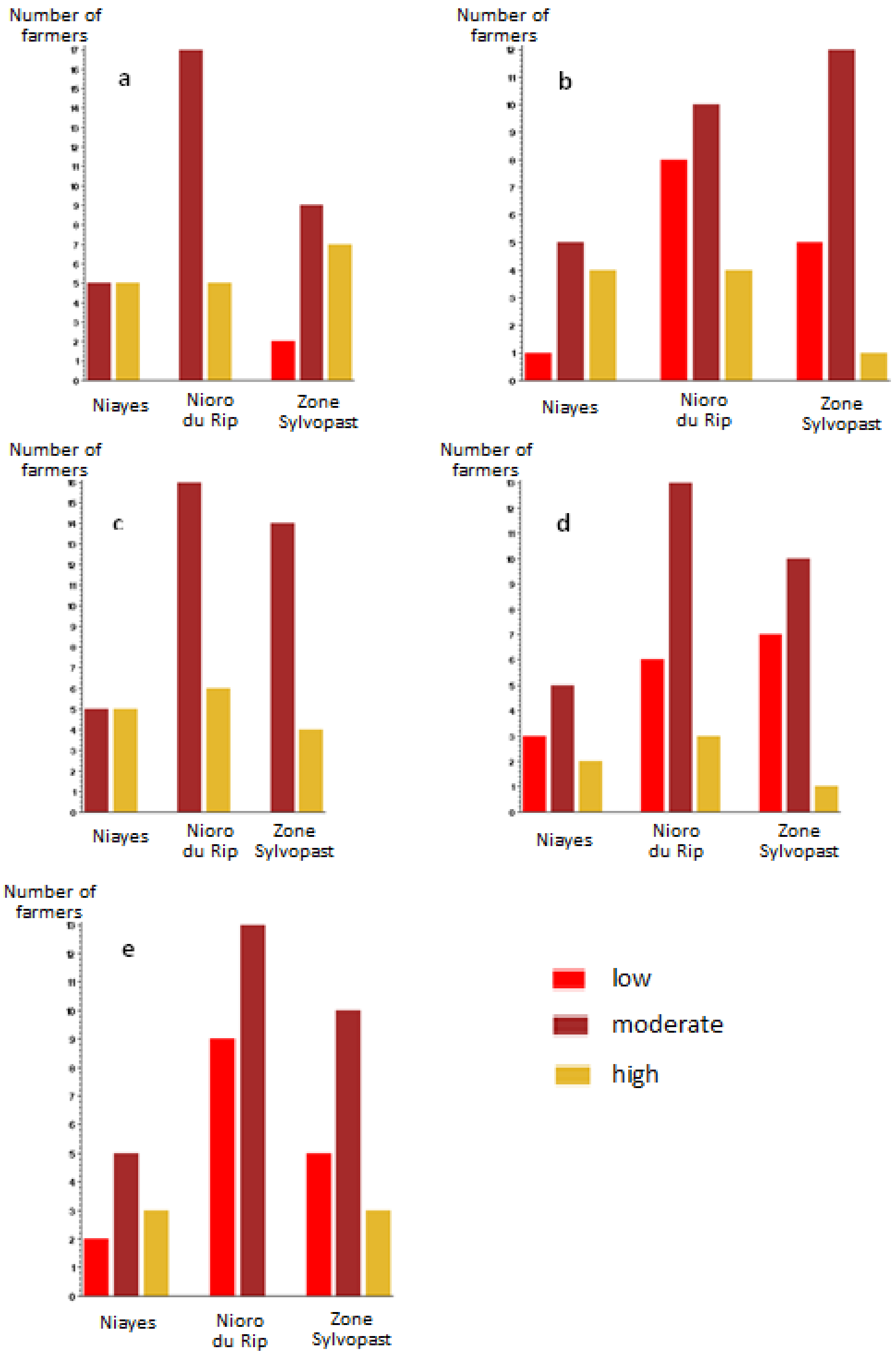

Figure 1. Frequency distribution of farmers by asset value class for each GAA: social (upper left; a), human (upper right; b), natural (middle left; c), financial (middle right; d) and physical (lowest; e) assets

3.1 Asset Value Scores by GAA

For visualization and comparison the asset values were aggregated into three classes: ‘low’ (score 0-4), ‘moderate’ (5-7) and ‘high’ (8-10). Figure 1 shows the frequency distribution of the number of farmers by GAAs for these asset classes concerning: social, human, natural, financial and physical capital. The ‘moderate’ class in the frequency distribution is clearly dominant for all assets, followed by the 'high' asset class. 'Low' asset classes are found for human, physical and financial assets. 'Low' classes in Niayes, Nioro du Rip and Zone Sylvopastoral reported, 20, 41 and 28 per cent for physical assets; for financial assets: 30, 27 and 39 per cent and for human assets: 10, 37 and 28 per cent, respectively. The social and natural capital is considered by the majority of the farmers as 'moderate' to 'high'. The results do not show clear trends that point to different prevailing distribution patterns between GAAs. Therefore, in the following paragraphs, we analyze the state and trend of land quality for all farmers with an occasional reference to specific outcomes by GAA.

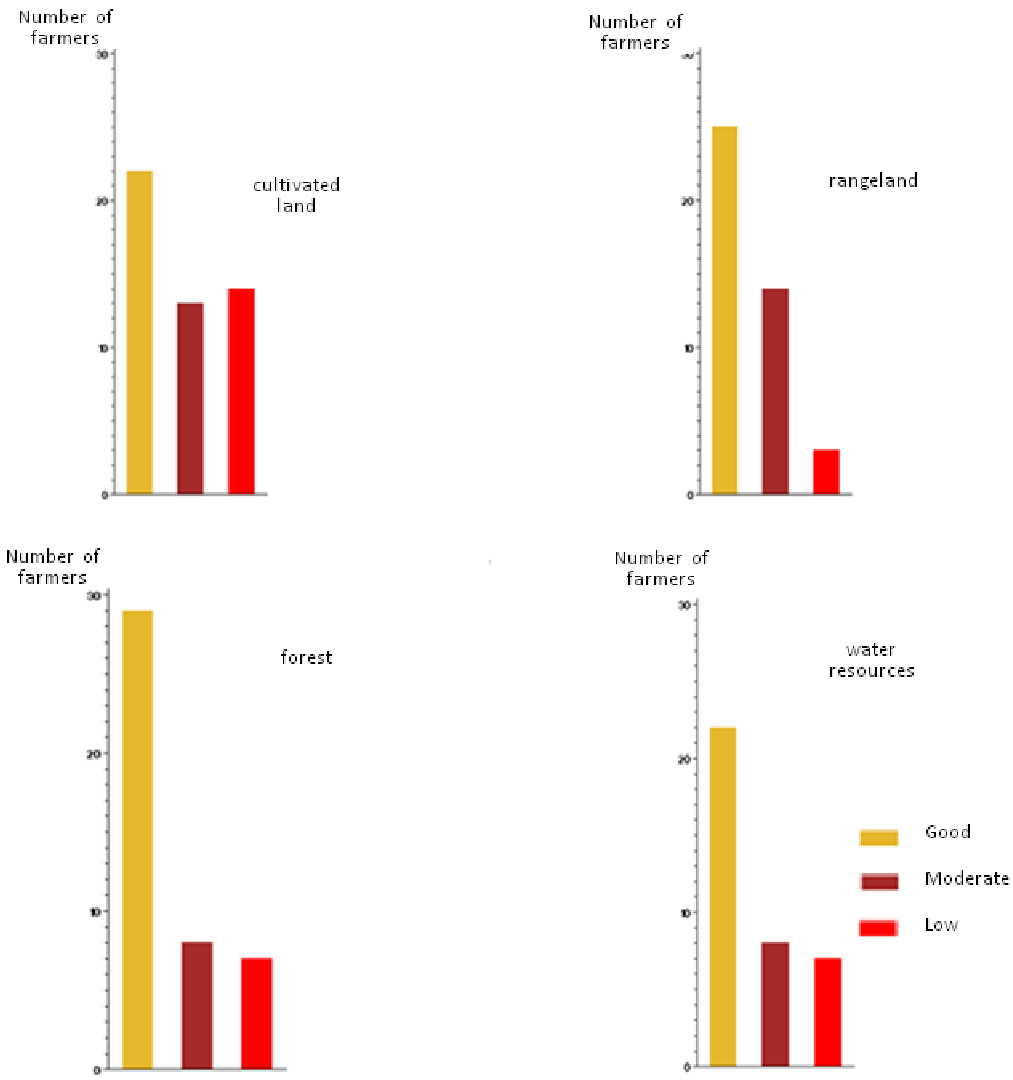

Figure 2. Frequency distribution of farmer responses on state of natural resource quality for: culitivated land (upper left), rangeland (upper right), water resources (lower left) and forest (lower right)

3.2 State and Trend of Land Quality

Of the 50 interviewed farmers 49, 42, 37 and 44 gave valid answers on the state of land quality for, crop land, rangeland, forest and water quality, respectively. Figure 2shows the frequency distribution of farmer responses on state of the natural resource quality for crop land, rangeland, forest and water, respectively. These responses were classified as 'low', 'moderate' and 'high'. For crop land 29 per cent was reported as 'low' quality. A closer look into the data showed that the 'low' category holds for 50 per cent of the farmers in Nioro du Rip, against 11 per cent of the farmers in Niayes and Zone Sylvopastoral. The state of rangeland was considered 'moderate' (33 per cent) to 'good' (60 per cent). Only some farmers in Niayes (13 per cent) and Nioro du Rip (11 per cent) reported 'low' quality rangelands. For the Zone Sylvopastoral the rangelands were qualified as 'moderate' (38 per cent) to 'good' (62 per cent). The overall scores for forest quality, 60 per cent 'good', 22 per cent 'moderate', 19 per cent 'low' and water resources 66 per cent 'good', 18 per cent 'moderate' and 16 per cent 'low' followed representative patterns for all three GAAs. Not all farmers responded or gave valid answers on the state of land quality. Of the 50 interviewed farmers 49, 42, 37 and 44 gave valid answers on the state of land quality for respectively: cultivated land, rangeland, forest and water quality.

Figure 3 shows the frequency distribution of farmer responses on trends of natural resource quality that were classified as 'rapidly decreasing', 'decreasing', 'stable', 'improving' and 'rapidly improving'. The results show that an alarming 62 per cent of the farmers indicated a 'decreasing' to 'rapidly decreasing' trend for crop land. A further analysis of the responses by GAA shows that 71 per cent of the farmers in Niayes and 76 per cent of the farmers in Nioro du Rip reported decreasing trends; in the Zone Sylvopastoral this percentage was less, 36, but still substantial.

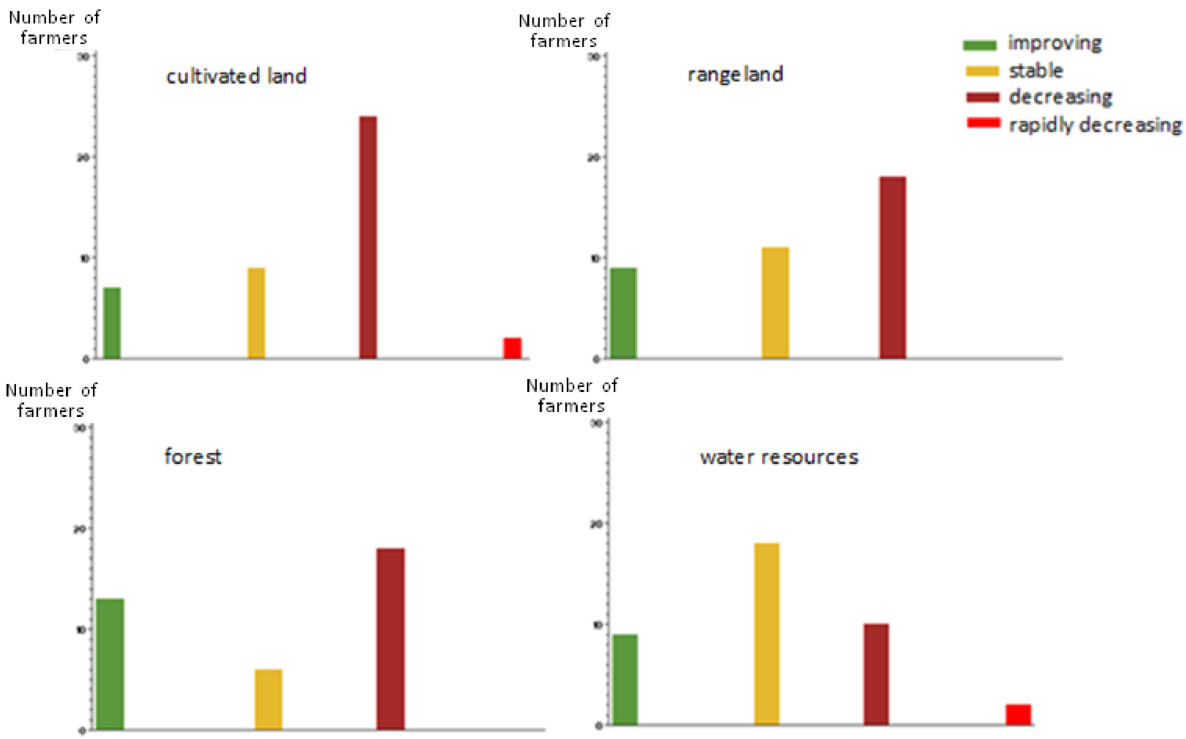

Figure 3. Frequency distribution of farmer responses on trend of land degradation for: crop land, (upper left), rangeland (upper right) forest (lower left) and water resources (lower right)

We also found similar overall decreasing trends for rangeland (47 per cent) and forest (49 per cent), whereby we note that farmers in Niayes reported a very high percentage (75 per cent) of decreasing rangeland quality, whereas farmers in Nioro du Rip and Zone Sylvopastoral reported lower decreasing rangeland trends of, respectively, 47 and 33 per cent. On the positive side we found a remarkably high percentage (71 per cent) of 'improving' forest in Niayes where Nioro du Rip and Zone Sylvopastoral recorded 29 and 23 per cent. Water resources showed in general a decreasing trend in quality for 31 per cent of the interviewed farmers. Especially,

Niayes reported high percentages of water resource degradation (50 per cent). Yet, in Nioro du Rip and Zone Sylvopastoral, respectively 71 and 79 per cent of the water resources were either stable or improving. We can conclude that, overall, the state of natural resource quality is of concern with percentages of 'low' quality varying between 7 (rangeland) and 29 (crop land) per cent. Yet, the (rapidly) decreasing land quality requires urgent attention as these percentages vary from 31 (water resources) to 62 (crop land) per cent. Furthermore, we note that in both state and trend the most affected areas are under crop land. Niayes and Nioro du Rip are the GAAs where most negative figures in state and trends of natural resource quality are reported.

3.3 State and Trend of Natural Resource Quality by Categorized Scores of Asset Values

In this section we analyze the association between state and trend of natural resource quality for the various asset values. Our working hypothesis is that lower asset values are indicative for natural resource degradation while higher classes correspond with ‘good’ quality. The idea of this premise is that farmers with less economic and natural endowments will have limited means to restore natural resources (e.g. Barbier, 2000; Tittonell and Giller, 2013) while richer farmers have more opportunities to maintain or increase the quality of their resource base. We conduct this analysis by comparing for the ordered state and trend classes of land quality the frequency distribution of categorical asset value classes and average differences of continuous asset value scores.

*Asset value classes***.** Table A 1 in the Annex shows a full reporting of frequency distribution for each of the asset value classes and corresponding state of land degradation. Yet, initial runs for the Chi-square test frequently reported low cell frequencies which makes test results invalid (e.g. Hopkins and Kenneth, 1978). Hence we decided to aggregate cell frequencies over individual assets and summarize the frequency for each of the asset value classes only. 错误!未找到引用源。 reports on these results and includes the expected frequency in case that asset value classes and qualitative judgments on land quality are independent. We note that most expected values are close to observed frequencies except for forest that also shows a significant Chi-square statistic (value 22.9406, probability <0.0001) whereas Chi-square tests for other natural resources show no significant influence (values of 3.1803, 4.1390 and 5.8051 with corresponding probabilities under the zero difference hypothesis of 0.5281, 0.3875 and 0.2142 for crop land, rangeland and water resources, respectively). A closer look at the ‘forest’ data shows that the deviations are more or less counterintuitive as for the ‘Good’ state of forest we find lower frequencies as expected for the ‘High’ asset value class and higher frequencies for the ‘Low’ asset class. The opposite holds for the ‘Degraded’ quality state of forests where frequencies for ‘High’ are higher as expected and ‘Low’ asset classes show lower frequency than expected. We can conclude that our premise, higher asset values would indicate ‘good’ resource qualities and lower asset values would indicate lower (‘Degraded’) natural resources, has proven to be incorrect. In the majority of the cases the Chi-square test clearly shows that there is no significant difference between expected independent outcomes and observed frequency distribution.

Table A 2 in the Annex shows the frequency distribution for each of the asset values and corresponding trends of natural resource quality. For the same reason of low cell frequencies we aggregated cell frequencies over individual assets. The resulting cell frequencies including the expected frequency under independence assumption are summarized in Table 6. Cell frequencies for ‘rapidly decreasing’ were still at a low level and for our Chi-square analysis aggregated with the ‘decreasing’ class. We find that most expected values are close to the observed ones. The Chi-square statistics (2.4395, 4.7678, 2.8564, 4.5742 with probabilities of 0.8752, 0.3120, 0.5821 and 0.5995 for crop land, rangeland, forest and water resources, respectively) confirm the minimal difference between observed and expected frequency distribution for all natural resources. Hence, we can conclude that the categorical asset values are not useful predictors for the trend of natural resource quality.

Table 5. Observed (and expected) frequency distribution for asset value classes and state of land quality by natural resource

Asset value class	Natural resource	Good	Moderate	Degraded	Total
High	crop land	27 (23.3)	13 (13.7)	12 (14.8)	52
	Rangeland	24 (26.7)	15 (15.0)	6 (3.2)	45
	forest	19 (24.3)	5 (8.8)	17 (7.7)	41
	water	26 (30.3)	8 (8.3)	12 (7.3)	46
Moderate	crop land	61 (65.1)	37 (38.4)	47 (41.4)	145
	rangeland	74 (73.2)	43 (41.0)	6 (8.7)	123
	forest	61 (62.4)	30 (22.7)	14 (19.8)	105
	water	86 (85.6)	25 (23.6)	19 (20.6)	130
Low	crop land	22 (21.5)	15 (12.7)	11 (13.7)	48
	rangeland	27 (25.0)	12 (14.0)	3 (3.0)	42
	forest	30 (23.1)	5 (8.4)	4 (7.3)	39
	water	33 (29.0)	7 (8.0)	4 (7.0)	44
Total	crop land	110	65	70	245
Total	rangeland	125	70	15	210
Total	forest	110	40	35	185

Total	water	145	40	35	220

Table 6. Observed (and expected) frequency distribution for asset value classes and trend of land quality by natural resource

Asset value	Natural resource	Improving	Stable	Decreasing	Rapidly decreasing	Total
High	crop land	9 (7.0)	9 (9.0)	21 (24.0)	3 (2.0)	42
	rangeland	5 (9.7)	15 (11.8)	21 (19.4)	0	41
	forest	17 (14.0)	5 (6.4)	18 (19.4)	0	40
	water	8 (9.6)	22 (19.3)	9 (10.7)	3 (2.1)	42
Moderate	crop land	21 (21.1)	26 (27.2)	75 (72.5)	5 (6.0)	127
	rangeland	31 (26.2)	28 (32.1)	52 (52.5)	0	111
	forest	37 (37.2)	16 (17.1)	53 (51.5)	0	106
	water	28 (27.0)	56 (54.0)	28 (30.0)	5 (6.0)	117
Low	crop land	5 (6.8)	10 (8.7)	24 (23.4)	2 (1.9)	41
	rangeland	9 (9.0)	12 (11.0)	17 (18.0)	0	38
	forest	11 (13.7)	9 (6.3)	19 (18.9)	0	39
	water	9 (8.3)	12 (16.6)	13 (9.2)	2 (1.8)	36
Total	crop land	35	45	120	10	210
Total	rangeland	45	55	90	0	190
Total	forest	65	30	90	0	185
Total	water	45	90	50	10	195

3.4 State and Trend of Natural Resource Quality by Asset Values Scores

In this section we report on the predictive power of the mean asset value scores by asset for state and trend of natural resource quality. Table 7 shows for each natural resource the mean of the scores and their standard deviation by asset and state of natural resources. The table includes an overall score for each of the asset value classes. For crop land we find that two (human and social) out of the six reported assets the lowest value corresponds to 'degraded' state and for water resources this occurred once (natural). For rangeland and forest all asset values for 'degraded' were highest or second highest. For the 'good' state of the natural resource quality we found that for crop land three assets (physical, human and natural) had the highest value and for rangeland one (financial). Forest and water resources all reported second or third for the 'good' state of the resource. We also note that the standard deviation is relatively large which makes it less likely that differences between the mean will be significant.

Table 7. Asset value scores, mean and standard deviation, by natural resource and state of land quality

Asset	State of land	Crop land		Rangeland		Forest		Water	
		mean	sdev	mean	sdev	mean	sdev	mean	sdev
Physical	degraded	4.93	2.09	5.33	2.08	7.00	1.91	6.29	2.36
	moderate	4.15	2.30	5.07	2.56	5.00	1.85	4.88	2.10
	good	5.18	3.11	4.64	2.87	4.14	3.00	4.41	2.82
Financial	degraded	5.36	2.59	5.00	4.36	5.57	2.82	5.86	2.48
	moderate	4.38	2.26	3.79	1.72	4.88	1.81	4.38	1.60
	good	4.64	2.04	5.40	2.16	4.50	2.28	4.48	2.38
Human	degraded	4.93	2.20	7.00	2.65	5.43	2.57	6.29	2.14
	moderate	5.00	2.89	5.43	2.47	4.63	2.00	5.25	2.71
	good	5.14	2.29	4.36	1.87	4.64	2.65	4.48	2.31
Natural	degraded	6.57	0.94	7.00	1.00	7.71	0.49	6.43	1.13
	moderate	6.54	1.27	6.29	1.82	6.00	1.20	6.63	1.85
	good	6.77	1.69	6.72	1.17	6.55	1.57	6.59	1.35
Social	degraded	6.50	1.74	7.33	1.15	6.86	6.86	7.43	1.40
	moderate	6.77	1.42	6.64	1.28	6.50	6.50	6.88	1.64
	good	6.50	2.18	6.32	2.21	6.27	6.27	6.14	1.98
Total	degraded	28.29	6.09	31.67	8.02	32.57	8.32	32.29	5.74
	moderate	26.85	7.49	27.21	7.99	27.00	5.61	28.00	7.35
	good	28.23	8.35	27.44	6.95	26.09	8.02	26.10	7.57

We test if asset value scores for the three natural resource quality classes are significantly different, that is, we compare scores for a) 'degraded' with 'moderate', b) 'degraded' with 'good', c) 'moderate' with 'good' and d) 'degraded' against the two other assessments.Table 8 presents the results. For crop land we do not find significant differences between asset value scores for the various states of natural resource qualities. For rangeland we find significant differences between 'moderate' and 'good' and between 'degraded' and 'good' for financial and human asset values. A closer look at Table 7 shows that for financial assets the 'moderate' score is lower as compared to the 'good', while for human asset value the score for 'degraded' is higher as compared to 'good'. For forest we find significant differences for physical, natural and total asset scores. For physical assets the scores for 'degraded' are higher as compared to 'good' and 'others' and this also holds for natural and total asset value scores. For water resources we find for human and total asset scores significant differences between higher 'degraded' scores as compared to the lower scores for the 'good' category.

Table 8. GLM-Anova results for asset value scores by asset, natural resource and state of natural resource quality

		Crop land		Rangeland			Forest			Water	
Asset		FValue	ProbF	FValue	ProbF		FValue	ProbF		FValue	ProbF
Physical	degraded vs moderate	0.575	0.452	0.023	0.881		2.164	0.150		1.060	0.309
	degraded vs good	0.078	0.781	0.172	0.680		6.311	0.017	**	2.819	0.101
	moderate vs good	1.226	0.274	0.224	0.639		0.634	0.431		0.190	0.665
	degraded vs others	0.095	0.760	0.085	0.773		4.621	0.039	**	2.104	0.155
Financial	degraded vs moderate	1.246	0.270	0.754	0.390		0.342	0.563		1.571	0.217
	degraded vs good	0.869	0.356	0.089	0.767		1.151	0.291		2.041	0.161
	moderate vs good	0.101	0.752	4.842	0.034	**	0.156	0.696		0.014	0.907
	degraded vs others	1.373	0.247	0.095	0.760		0.795	0.379		2.139	0.151

Human	degraded vs moderate	0.006	0.940	1.343	0.254		0.382	0.541		0.720	0.401	
	degraded vs good	0.062	0.804	4.109	0.050	**	0.528	0.472		3.294	0.077	*
	moderate vs good	0.026	0.874	2.255	0.141		0.000	0.991		0.663	0.420	
	degraded vs others	0.032	0.859	2.702	0.108		0.544	0.466		1.981	0.167	
Natural	degraded vs moderate	0.004	0.952	0.631	0.432		5.932	0.020	**	0.071	0.791	
	degraded vs good	0.176	0.677	0.105	0.747		3.923	0.056	*	0.070	0.793	
	moderate vs good	0.228	0.635	0.847	0.363		0.944	0.338		0.005	0.946	
	degraded vs others	0.035	0.852	0.343	0.562		6.058	0.019	**	0.085	0.772	
Social	degraded vs moderate	0.138	0.712	0.325	0.572		0.131	0.719		0.335	0.566	
	degraded vs good	0.000	1.000	0.759	0.389		0.500	0.484		2.750	0.105	
	moderate vs good	0.167	0.685	0.258	0.614		0.084	0.774		0.997	0.324	
	degraded vs others	0.050	0.824	0.555	0.461		0.330	0.570		1.362	0.250	
Total	degraded vs moderate	0.245	0.623	0.902	0.348		1.982	0.168		1.290	0.263	
	degraded vs good	0.001	0.982	0.881	0.354		3.815	0.059	*	4.053	0.051	*
	moderate vs good	0.273	0.604	0.008	0.927		0.083	0.775		0.424	0.519	
	degraded vs others	0.096	0.758	0.960	0.333		3.349	0.076	*	2.819	0.101	

*significance at 10% level , **significance at 5% level

Finally, we analyze if the scores for asset values are correlated to the trend of natural resource quality. 错误!未找到引用源。 shows the average asset value scores for the trend of natural resource quality. For crop land and rangeland we only find for financial assets that lower scores correspond to the 'degrading' trend, for all other asset values the 'decreasing' category has the highest or second to the highest score. For forest the natural and human asset value scores were lowest for 'decreasing'. For water we found that lowest asset scores for physical, financial, natural, social, and total were given for the 'decreasing' categories. Highest scores for crop land that corresponded to the 'improving' trend were found for the physical, financial and total asset values. For rangeland only physical assets had the highest score for 'improving'. For forest we found highest scores for 'improving' for physical, financial, human and total; for water this holds for the assets financial, natural and social.

Table 9. Asset values scores by natural resources and trend of land quality

		Crop land		**Rangeland**		**Forest**		**Water**	
		mean	sdev	Mean	sdev	mean	sdev	mean	sdev
Physical	improving	5.57	2.30	5.33	2.55	5.69	2.81	4.89	1.90
	stable	4.52	2.66	4.36	2.73	3.17	2.93	5.11	3.01
	decreasing	5.44	2.83	5.17	2.64	4.94	2.29	4.83	2.66
Financial	improving	6.43	2.23	5.11	1.76	4.92	2.75	4.56	2.30
	stable	4.73	2.30	5.55	2.42	4.00	1.67	5.39	2.17
	decreasing	3.67	1.32	4.11	2.49	4.67	2.30	4.08	2.54
Human	improving	5.00	2.77	4.11	2.03	6.23	2.49	5.00	3.16
	stable	4.88	2.32	4.64	2.01	3.83	0.75	4.94	1.86
	decreasing	5.67	2.55	5.78	2.16	4.22	2.24	5.25	2.60
Natural	improving	6.57	1.51	6.11	1.05	6.69	1.75	6.78	1.20
	stable	6.67	1.24	7.09	1.45	6.83	1.47	6.78	1.40
	decreasing	6.67	1.87	6.50	1.58	6.61	1.24	6.25	1.60
Social	improving	6.71	2.14	6.44	1.94	6.54	1.71	6.78	1.99
	stable	6.30	1.83	6.27	2.00	6.83	1.94	6.61	1.85
	decreasing	7.44	1.59	6.56	1.92	6.33	2.06	5.92	2.11
Total	improving	30.29	8.12	27.11	5.53	30.08	8.02	28.00	7.21
	stable	27.09	7.25	27.91	7.42	24.67	6.92	28.83	7.37

decreasing	28.89	7.87	28.11	8.10	26.78	7.46	26.33	8.07

错误!未找到引用源。 reports on the statistical significance of differences that were found for asset value scores by trend category. We compare, by asset and natural resource, the scores for a) 'improving' against 'stable', b) 'improving' against 'decreasing', c) 'stable' against 'decreasing' and d) 'decreasing' against the average of all other scores. For crop land we find significant differences for financial assets for the comparison between 'improving' against 'stable', 'improving' against 'decreasing' and 'decreasing' against the average of all other scores. As we discussed in the previous paragraph, the scores of values follows the expected high scores for 'improving' and lowest for 'decreasing' trends, with a score in between these extremes for 'stable'. For rangeland we found significant differences for the human asset when we compare 'improving' against 'decreasing' and 'decreasing' against the average of all other scores. Yet, the highest scores were given for 'decreasing' and lowest scores for 'improving'. Forest reported significant differences in scores for the physical asset when comparing the 'improving' against 'stable', whereby we remark that the score for 'improving' was almost twice as high as for 'stable'. Also for human asset we found significant differences between 'improving' against 'stable' and 'improving' against 'decreasing', with highest scores for the 'improving' category, lowest for 'stable' and with 'decreasing' in between these scores. For water we did not find any significance in the differences between the asset value scores.

Table 10. GLM-Anova results for asset value scores by asset, natural resource and trend of natural resource quality

		crop land			**rangeland**			**Forest**			**water**	
Asset		FValue	ProbF		FValue	ProbF		FValue	ProbF		FValue	ProbF
Physical	improv. vs stable	0.920	0.343		0.665	0.420		3.930	0.056	*	0.041	0.841
	improv. vs decreas.	0.009	0.925		0.024	0.878		0.634	0.432		0.002	0.963
	stable vs decreas.	0.872	0.355		0.629	0.433		2.134	0.153		0.077	0.783
	decreas. vs others	0.149	0.701		0.136	0.714		0.342	0.563		0.031	0.862
Financial	improv. vs stable	3.622	0.063	*	0.173	0.680		0.610	0.440		0.776	0.384
	improv. vs decreas.	6.509	0.014	**	1.109	0.300		0.087	0.770		0.213	0.647
	stable vs decreas.	1.724	0.196		2.596	0.116		0.349	0.559		2.284	0.139
	decreas. vs others	5.127	0.028	**	2.581	0.117		0.063	0.803		1.177	0.285
Human	improv. vs stable	0.014	0.905		0.313	0.579		4.945	0.033	**	0.003	0.956
	improv. vs decreas.	0.299	0.587		3.824	0.059	*	6.381	0.016	**	0.054	0.817
	stable vs decreas.	0.749	0.391		2.041	0.162		0.143	0.708		0.114	0.738
	decreas. vs others	0.585	0.448		4.265	0.046	**	1.180	0.285		0.104	0.749
Natural	improv. vs stable	0.026	0.871		2.300	0.138		0.038	0.847		0.000	1.000
	improv. vs decreas.	0.018	0.894		0.439	0.512		0.023	0.881		0.707	0.406
	stable vs decreas.	0.000	1.000		1.154	0.290		0.102	0.751		0.990	0.326
	decreas. vs others	0.007	0.932		0.047	0.830		0.091	0.765		1.100	0.301
Social	improv. vs stable	0.291	0.592		0.038	0.846		0.096	0.758		0.043	0.836
	improv. vs decreas.	0.625	0.433		0.020	0.890		0.086	0.772		0.989	0.327
	stable vs decreas.	2.741	0.105		0.144	0.707		0.303	0.585		0.901	0.349
	decreas. vs others	1.687	0.200		0.096	0.758		0.288	0.595		1.256	0.270
Total	improv. vs stable	1.055	0.310		0.058	0.812		2.089	0.157		0.073	0.789
	improv. vs decreas.	0.137	0.713		0.110	0.742		1.429	0.240		0.250	0.620
	stable vs decreas.	0.409	0.526		0.005	0.943		0.349	0.559		0.788	0.381
	decreas. vs others	0.005	0.946		0.062	0.804		0.053	0.820		0.608	0.441

*significance at 10% level , **significance at 5% level

4. Conclusions

Answering the question that is posed in our title, we have to conclude that asset values in general do not correlate straightforwardly and unequivocally with state and trend of natural resource quality. For our categorical asset value classes as well as for the continuous representation of scoring levels we did not find assuring relationships which indicate that asset values have a predictive power for natural resource quality. Hence we can state that our working hypothesis that relates poor farmers to a higher incidence of land degradation is proven to be incorrect. Obviously, adaptation to resource-conserving technologies, possibly supported by local institutions, is not related to farmers' endowments (Scherr, 2000).

For the state of forest we found some evidence of differences but these pointed to counterintuitive results of higher asset values that were related to 'degraded' classes. There might be a possibility that trend of natural resource quality for forests can be derived from asset value scores for physical and human.

The results refer to the well-known fact that land degradation is a complex process that is influenced by many factors, most of which are unknown or unobserved. This bias in the observed data makes it also difficult to establish a relationship that clearly measures the effect of an asset on the state and trend of land quality. Of course, the number of factors could be extended and each component of individual assets could be considered as an individual explanatory factor, yet, problems of overfitting and parameter identification, where multiple sets of parameters generate the same observations distribution, looms large.

The approach in a follow-up study could use various techniques (principal component analysis or kernel density regression) to select a limited number of location specific components of asset values that are related to the state and trend of natural resource quality. Possibly accompanied with randomized control trials where farmers are allowed to experiment with certain assets and the quality of the natural resource base is carefully monitored and quantified. The approach would strengthen the empirical basis of further research and hopefully be supportive in improving the decision makers' interventions.

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Notes

Note 1. This study tested the consistency of expert judgments by a cross-comparison of mapping units with identical characteristics for annual rainfall, soil suitability, slope, population density and livestock density. The study concluded that experts had a high consistency in their judgment and gave reliable assessment on the degree of land degradation.

Note 2. A GAA is defined as a watershed or an area of several 100 square kms that is representative for the country's prevailing land uses, sustainable land management activities and type and extent of land degradation.

Appendixes

Table A 1. Frequency distribution of asset value classes and state of land quality by asset and natural resource

Asset	Asset class	Land quality	Rainfed	Rangeland	Forest	Water
Physical	Low	Good	7	10	11	11
		Moderate	5	4	2	2
		Low	4	1	0	1
	Moderate	Good	11	11	8	14
		Moderate	7	8	6	6
		Low	9	2	4	4
	High	Good	4	4	3	4
		Moderate	1	2	0	0
		Low	1		3	2
Financial	Low	Good	7	6	9	10
		Moderate	6	5	1	3
		Low	3	2	2	2
	Moderate	Good	13	15	12	15
		Moderate	6	9	6	5
		Low	8	0	3	4
	High	Good	2	4	1	4
		Moderate	1	0	1	0
		Low	3	1	2	1
Natural	Low	Good	0	0	0	0
		Moderate	0	0	0	0
		Low	0	0	0	0
	moderate	Good	13	18	16	21
		Moderate	9	9	7	5
		Low	12	2	2	5
	high	Good	9	7	6	8
		Moderate	4	5	1	3
		Low	2	1	5	2
Human	low	Good	6	9	10	10
		Moderate	4	3	2	2
		Low	4		1	1
	moderate	Good	12	15	8	15
		Moderate	6	7	5	4
		Low	8	1	4	4
	high	Good	4	1	4	4
		Moderate	3	4	1	2

		Low	2	2	2	2
Social	low	Good	2	2	0	2
		Moderate	0	0	0	0
		Low	0	0	1	0
	moderate	Good	12	15	17	21
		Moderate	9	10	6	5
		Low	10	1	1	2
	high	Good	8	8	5	6
		Moderate	4	4	2	3
		Low	4	2	5	5

Table A 2. Frequency distribution of asset value classes and trend of land quality by asset and natural resource

	Asset Value	**Trend**	**Rainfed**	**Rangeland**	**Forest**	**Water**
Physical	low	improving	1	3	3	2
		stable	3	4	4	4
		decreasing	9	6	6	4
		rapidly decreasing	1	0	0	1
	moderate	improving	5	5	7	7
		stable	4	6	2	11
		decreasing	14	9	10	4
		rapidly decreasing	1	0	0	1
	high	improving	1	1	3	0
		stable	2	1	0	3
		decreasing	1	3	2	2
		rapidly decreasing	0	0	0	0
Financial	low	improving	1	2	5	4
		stable	3	3	3	3
		decreasing	8	8	5	5
		rapidly decreasing	1	0	0	1
	moderate	improving	4	7	6	5
		stable	5	5	3	11
		decreasing	13	8	11	4
		rapidly decreasing	1	0	0	1
	high	improving	2	0	2	0
		stable	1	3	0	4
		decreasing	3	2	2	1
		rapidly decreasing	0	0	0	0
Natural	low	improving	0	0	0	0
		stable	0	0	0	0
		decreasing	0	0	0	0
		rapidly decreasing	0	0	0	0
	moderate	improving	5	8	9	6
		stable	6	6	4	11
		decreasing	17	12	12	9

		rapidly decreasing	1	0	0	1
	high	improving	2	1	4	3
		stable	3	5	2	7
		decreasing	7	6	6	1
		rapidly decreasing	1	0	0	1
Human	low	improving	3	4	3	3
		stable	2	4	2	4
		decreasing	7	2	7	3
		rapidly decreasing	0	0	0	0
	moderate	improving	2	4	5	3
		stable	6	5	4	12
		decreasing	13	12	9	4
		rapidly decreasing	2	0	0	2
	high	improving	2	1	5	3
		stable	1	2	0	2
		decreasing	4	4	2	3
		rapidly decreasing	0	0	0	0
Social	low	improving	0	0	0	0
		stable	2	1	0	1
		decreasing	0	1	1	1
		rapidly decreasing	0	0	0	0
	moderate	improving	5	7	10	7
		stable	5	6	3	11
		decreasing	18	11	11	7
		rapidly decreasing	0	0	0	0
	high	improving	2	2	3	2
		stable	2	4	3	6
		decreasing	6	6	6	2
		rapidly decreasing	2	0	0	2