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Methods for Delineating Degraded Land at Citarum Watershed, West Java, Indonesia

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ABSTRACT

Accurate information on the extent and spatial location of degraded lands is very important to plan their rehabilitation. So far, various institutions issue different estimation on the extent of degraded land in Indonesia led to big confusion for rehabilitation planning. Ministry of Forestry estimates around 30.2 million ha of degraded land both inside and outside forestry area throughout Indonesia based on data released in 2007. Ministry of Forestry implementes the so called scoring method in delineating degraded land. Criteria used in the scoring methods are: land cover, slope steepness, erosion, and management. Scoring method applies different weight to each of those criteria. This study aimed to analyze accuracy of scoring method and to compare it to propose alternative methods in delineating degraded land such as: a) Inconsistency of land use, and b) Combination of Inconsistency of land use and scoring method. The accuracy of these methods were obtained by comparing to the field observation. The slope map was derived from SRTM 30 m, soil map was obtained from Soil Research Institute and land cover/land use from Ministry for Environment. Using GIS analysis, those maps were used to compose land capability classification (LCC) and inconsistency of land use. The study showed that scoring method had 66% accuracy in delineating degraded land. When scoring method was combined with Inconsistency method the accuracy increased about 7%.

Keywords: Degraded land, inconsistency of land use, land capability class, scoring method,

INTRODUCTION

In year 2030, an addition of 3.57 million ha land will be required to achieve sufficient rice production in Indonesia. Dry land is the most viable option to fulfill these requirements. Based on an inventory made by BBSDLP (Balai Besar Sumberdaya Lahan Pertanian), there are still some 22 million ha suitable area available for agriculture production (Las and Mulyani 2008). Among 7 million ha of those land are suitable for food crop production and the rest are for perennial crops. But, utilization of those lands for food crop production are confronted by degraded land problems. Based on estimation made by Ministry of Forestry in 2007, around 30.2 million ha of degraded land both inside and outside forestry area throughout Indonesia (Dirjen RLPS 2007). Ministry of Forestry implemented the so called scoring method in estimating extent of degraded land. Criteria used in the scoring methods are: land cover, slope steepness, erosion, and management. Scoring method applies different weight to each of those criteria. Scoring method has been adopted as standard method to determine degraded land in Indonesia.

Based on study made by Barus *et al.* (2011), scoring method has some shortcoming when it is used to plan effective rehabilitation in a particular area. Due to its nature, scoring method cannot be used precisely to pin point specific parameter dominating the land degradation process. In the light of this problem and the necessity to have precise map of degraded land in REDD+ scheme (Reducing Emissions from Deforestation and Forest Degradation), a modified approach should be striven for. This study aimed to analyze accuracy of scoring method and proposed alternative method in delineating degraded land.

Based on Tarigan *et al.* (2008), nowadays there are only two significant governmental programs in rehabilitation of degraded land. These are: a) GERHAN – Gerakan Nasional Rehabilitasi Hutan dan Lahan (National Movement for Rehabilitation of Degraded Forest and Land) coordinated by Ministry of Forestry and b) PUKLT - Pengembangan Usahatani Konservasi Lahan Terpadu (Integrated Development of Farming Conservation) coordinated by Ministry of Agriculture. But, coverage of GERHAN and PUKLT program area still very limited compared to the actual existence of million ha of degraded land. Much promising scheme such as REDD++ should be expected. But, REDD++ require accurate and unified map on the extent of degraded land in Indonesia. Consequently, robust method should be available to produce such map.

MATERIALS AND METHODS

Time and Location

The research was conducted in 2011 at Upper Citarum watershed. GIS processing using ArcGIS 9.3 was carried out in Soil and Water Conservation Laboratory, Department of Soil and Land Resources, Bogor Agricultural University.

Data collection

In delineating degraded land, scoring method as well as alternative methods required numerous spatial data. Type of data collected and their sources are listed in Table 1.

Data Processing and Analysis

GIS (Geo-Information System) procedures using ArcGIS 9.3 was used to determine spatial distribution of scores in Upper Citarum Catchment both in scoring method as well in alternative methods.

Scoring Method

Scoring method implemented GIS overlaying procedures to delineate different degree of land degradation based on criteria, weight and scores (Suryani and Tarigan 2009) as it is shown in Table 2. Calculated scores obtained using category as listed in Table 2 will be used to determine degree of land degradation as shown in Table 3. Graphically, data processing for scoring method using GIS analysis is shown in Figure 1.

Inconsistency of Land Use

Based on Rustiadi *et al.* (2010), Indonesian government (*f.e.* Ministry for Environment) has adopted land capability classification (LCC) as one method to determine carrying capacity for regional land use planning (RTRW). As a general rule areas that are categorized as classes VII-VIII in LCC was (Table 4) cannot be used as an agricultural area. Inconsistency occurs when areas having classes VII-VIII are used for intensive agriculture such as ladang/tegalan, mixed-farming (*kebun campuran*), and plantation.

To determine inconsistency of land use, both LCC and land use map were required. The LCC derived using Klingebiel and Montgomery method as modified by Arsyad (2010). Land use map was obtained from Ministry for Environment. The LCC map was derived using the following criteria (Table 4).

Inconsistency of land use map was derived based on the following diagram (Figure 2). GIS

Table 1. Type of data spatial and their sources.

Type of Data	Sources	Remarks
Slope map	SRTM 30 m	Obtained from LAPAN
Land use map	Ministry for Environment	Year 2007
Degraded land map	BPDAS Citarum Ciliwung	Year 2007
Soil data	Soil Research Institute (PPT)	
Rain erosivity	Bols	
Erosion index	GIS Analysis	
Land capability class	GIS Analysis	

Table 2. Criteria and weight used to calculate scores for related degraded land.

Criteria	Category (score)	Weight (%)
Slope	Flat (5); Gentle (4); Moderately (3); Steep (2); Very steep (1)	20
Land cover	Very good (5); Good (4); Moderate (3); Bad (2); Very bad (1)	50
Erosion	Slight (5; Moderate (4); Severe (3); Very severe (2)	20
Management	Good (5);Moderate (3); Bad (1)	10

Sources: Dirjen RLPS (2007).

Table 3. Degree of land degradation based on the calculated scores.

Degree of degradation	Total score		
	Protected forest area	Agriculture area	Other Protected areas
Very degraded	120 - 180	115 - 200	110 - 200
Degraded	181 - 270	201 - 275	201 - 275
Moderately degraded	271 - 360	276 - 350	276 - 350
Potentially degraded	361 - 450	351 - 425	351 - 425
Not degraded	451 - 500	426 - 500	426 - 500

Sources: Dirjen RLPS (2007).

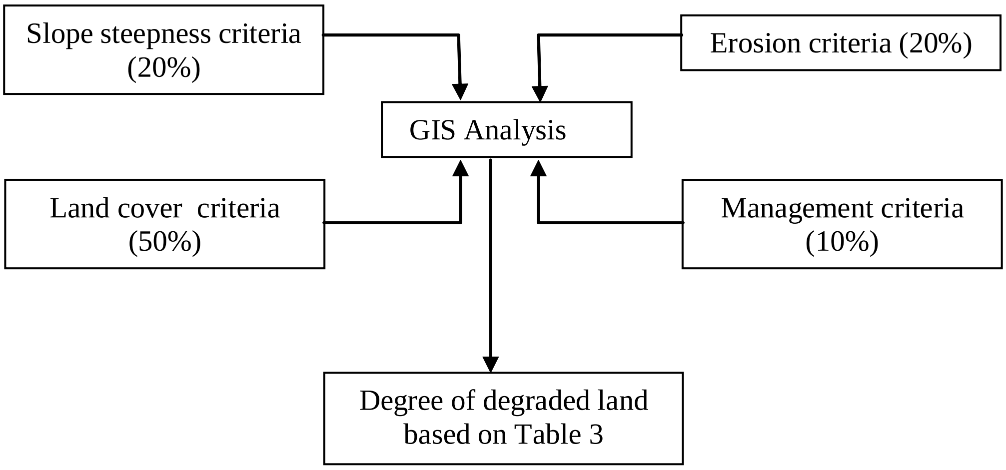

Figure 1. Delineation of degraded land based on scoring method.

Tabel 4. Land capability classification criteria.

Limiting factors	Land capability classes							
	I	II	III	IV	V	VI	VII	VIII
Slope (l)	l_0	l_1	l_2	l_3	l_0	l_4	l_5	l_6
Erosion level (e)	0	1	2	3	(**)	4	5	(*)
Solum depth (k)	0	1	2	2	(*)	3	(*)	(*)
Soil texture (t)	1-3	1-3	1-4	1-4	(*)	1-4	1-4	5
Permeability (p)	2-3	2-3	2-4	2-4	1	(*)	(*)	5
Drainage (d)	1	2	3	4	5	(**)	(**)	0

Source: (Arsyad 2010 - modified). (*) : can be of any value and (**) : not applicable.

analysis was used to compose LCC map using input criteria as listed in Table 4. Further GIS analysis was carried out to compare LCC map with coresponding year of land use map. If agricultural areas in landuse map were situated in LCC classes VII or VIII, then the areas were identified as inconsistent.

Field Observation

Field observation was carried out to verify extent of degraded land delineated in the field. The criteria used in the field for verification was the existence of observable erosion. When there were sign of visible rill erosion and significant top soil had been eroded then the area were confirmed as degraded land. View of Google earth image was very detail in Upper Citarum watershed helping us to identify extent of degraded land in the field with high accuracy. Final map of degraded land based on field observation was composed by combining visual observation in the field and their boundary was interpreted from Google earth image using software avaiable at http://www.birdtheme.org/useful/googletool largemap.html.

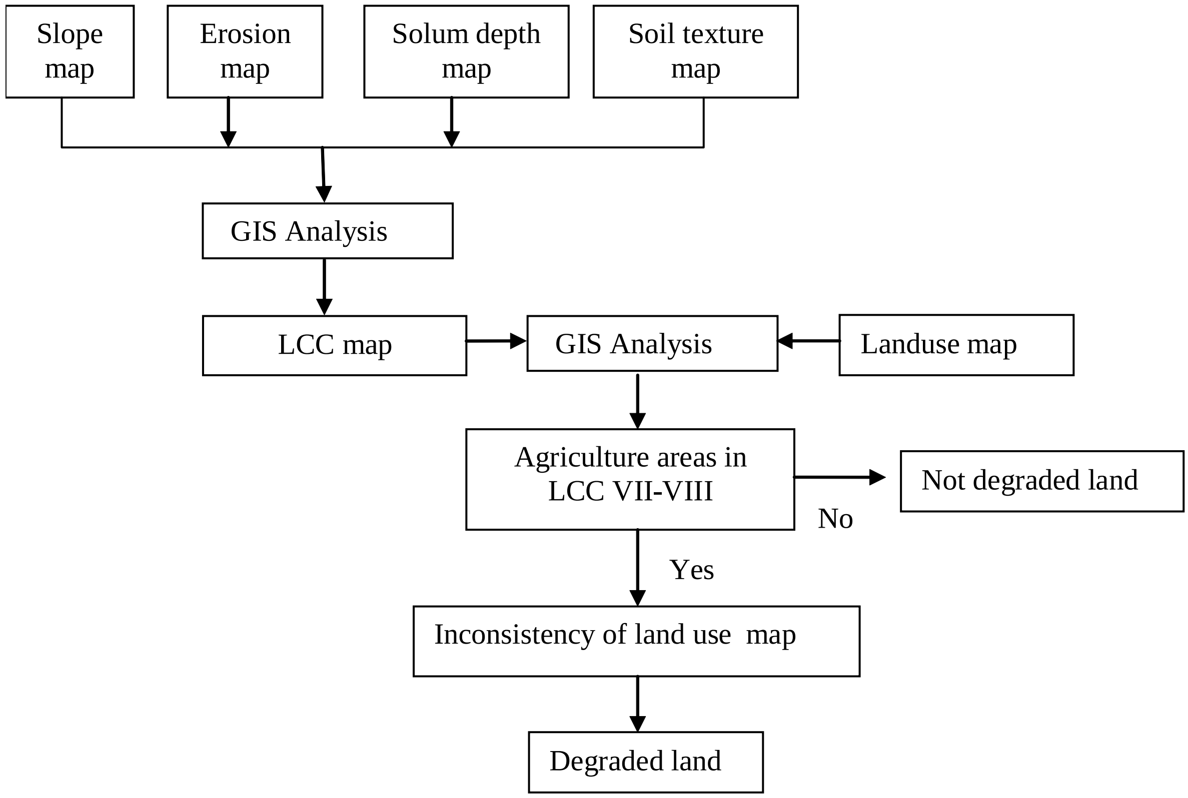

Figure 2. Delineation of degraded land using inconsistency land use map.

RESULTS AND DISCUSSION

Accurate information on the extent and location of degraded lands is very important to plan for their rehabilitation. Several institutions published degraded land data based on the criteria used by each institution (for example Ministry of Forestry and Ministry for Agriculture). Different criteria used in determining degraded land have resulted in different estimation of its extent. Ministry of Forestry (MoF) is one among several institutions which published degraded land data regularly, either inside or outside forest area. In 2007, MoF published that 19.5 million ha inside and 10.7 million ha outside forest area were categorized as degraded and severely degraded land. In delineating degraded land MoF used scoring method. In this study, The accuracy of scoring method was evaluated and other alternative methods were proposed.

Accuracy of Scoring Method (SM) in Delineating Degraded Land

To examine accuracy of scoring method, degraded land in Upper Citarum Watershed was delineated and then compared to the field observation. Actually, there are four degrees of land degradation as it is listed in Table 3. But for the purpose of comparison with field observation, only 2 degrees of land degradation were used in this study. These were very degraded and degraded degrees. During field observation, degraded and very degraded land were identified by the presence of observable erosion (Junaidi and Tarigan 2012). For simplicity both category will be further referred as degraded land. The result of comparison between scoring method (SM) and field observation (FO) are graphically shown in Figure 3 and the quantitative different is shown in Table 5. Group I identified areas where SM and FO were in agreement. Meanwhile, group II and III showed areas where SM and FO were not in agreement or misclassified.

Based on the field observation, extent of degraded lands in Upper Citarum were 29,668 ha (Group I + III). Using scoring method, only 19,544 ha (Group I) or 66% from total amount of these degraded land was correctly delineated (Group I). It misidentified the extent of degraded land and misclasified it as not degraded about 30% compared to field observation (Group III).

On the other hand, some 18,830 ha (Group II) of Upper Citarum watershed were misclassified by scoring method as degraded land which was actually not degraded in the field. These area were situated mainly in North Lembang, Ciparay and Pengalengan

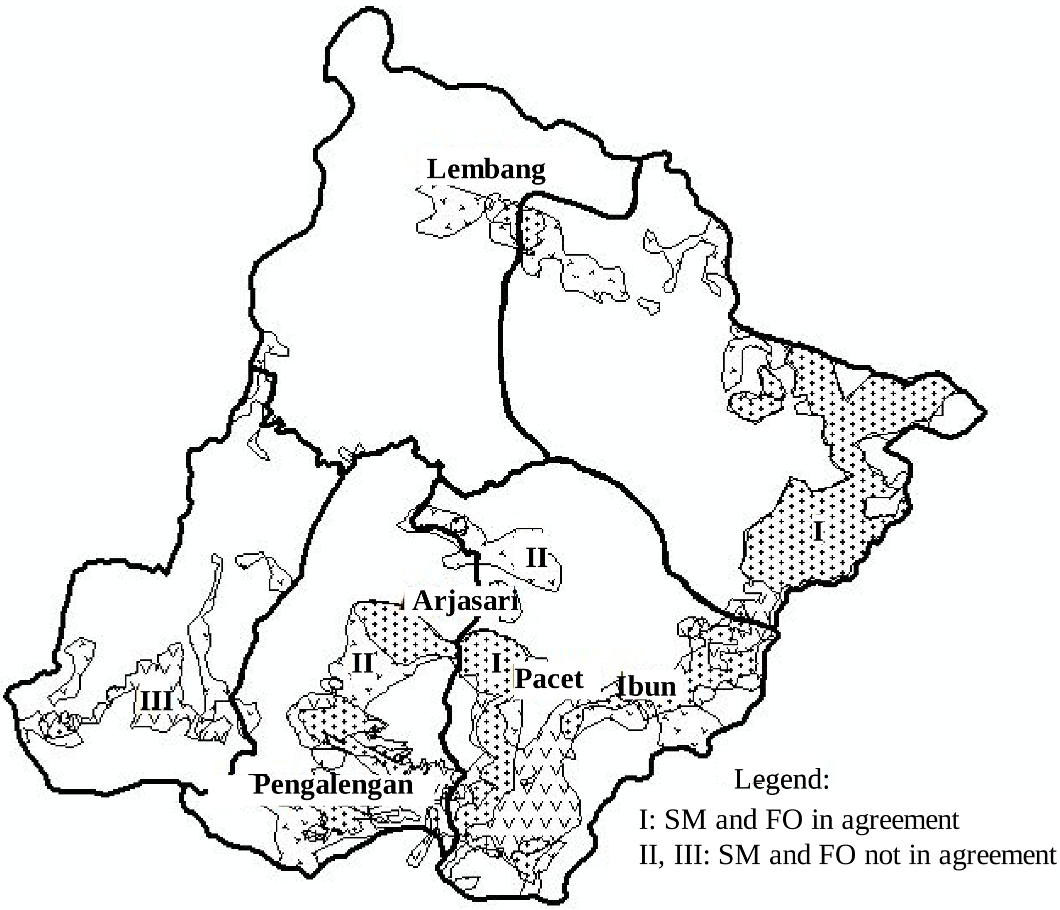

Figure 3. Graphical comparation of degraded land obtained by scoring method (SM) and field observation (FO) in Upper Citarum Watershed.

Table 5. Matrix comparison of degraded land obtained by scoring method and field observation.

Scoring method (SM)	Field Observation (FO)		
	Degraded	Not degraded	Total area
Degraded	Group I (19,554 ha)	Group II (18,830 ha)	38,384 ha
Not degraded	Group III (10,114 ha)	Group IV (349,786 ha)	359,900 ha
Total area	29,668 ha	368,616 ha	398,284 ha

Sub-Districts. There are at least two reasons why scoring method misclassified these areas: (a) tea plantation area has less vegetation coverage compared to the forest. In scoring method, vegetation coverage contributes to 50% of the total score (Table 2). Due to the low vegetation coverage, tea plantation in these areas was categorized in scoring method as degraded. In reality, tea plantation had significantly closed canopy coverage to prevent severe erosion leading to land degradation processes and there were no observable rill erosion seen in the tea plantation, (b) agriculture area with good condition of terraces were also classified by scoring method as degraded land. Due to the less vegetation coverage, these areas were also classified by scoring method as degraded land. In reality, soil is sufficiently preserved in good terraced agricultural areas preventing land degradation (Figure 4).

Meanwhile, some 10,114 ha degraded land (Group III) was misclassified by scoring method as not degraded which was actually degraded based on the field observation. These areas were mostly situated in class VII and VIII in land capability classification (LCC), but they were utilized as tegalan/ladang which accelerate degradation process. The vegetation coverage was actually good enough, but due to the very intensive erosion

Source: Cita-Citarum

Figure 4. Good terraced agriculture area which is misclassified as degraded land in scoring method in upper citarum watershed.

process in in these particular type of LCC, the land were easily degraded. It can be concluded that class VII and VIII in LCC had high risk to become degraded when they were utilized as agricultural area.

Alternative Method Used to Determine Degraded Land

As it was already seen in the previous section, scoring method did not take into consideration LCC (land capability classification). LCC can be a determining factor in delineating degraded land. Based on LCC, areas categorized as class VII and VIII should not be utilized as agricultural area. This concept will be considered in the proposed alternative method called Inconsistency of Land Use.

Inconsistency of Land Use

Based on Ministry for Environmental Decree (PERMEN LH No. 17/2009), land capability classes (LCC) should be used to determine carrying capacity for regional land use planning (RTRW) in Indonesian (Rustiadi *et al*. 2010). As a general rule, areas that are categorized as classes VII-VIII in LCC cannot be used as an agricultural area. Inconsistency occurs when areas having classes VII-VIII are used for intensive agriculture such as ladang/tegalan, mixed-farming (kebun campuran), and plantation. The inconsistency will accelerate land degradation. Scoring method did not take into consideration this aspect.

Inconsistencies of land use were derived by overlaying LCC and land use map. Agriculture area that were situated at Class VII and VIII in LCC were

Table 6. Matrix comparison of degraded land obtained by inconsistency of land use method and field observation.

Inconsistency method	Field observation (FO)		
	Degraded area^{-1}	Not degraded area^{-1}	Total area
Degraded	Group I (12,660 ha)	Group II (14,858 ha)	27,518 ha
Not degraded	Group III (16,937 ha)	Group IV (353,758)	379,695 ha
Total area	29,668 ha	368,616 ha	398,284 ha

Table 7. Matrix distribution of degraded land obtained by combined inconsistency of land use and scoring method and field observation.

Inconsistency method	Field observation (FO)		
	Degraded area^{-1}	Not degraded area^{-1}	Total area
Degraded	Group I (21,693 ha)	Group II (26,147 ha)	47,840 ha
Not degraded	Group III (7,975 ha)	Group IV (342,469 ha)	350,444 ha
Total area	29,668 ha	368,616 ha	398,284 ha

categorized as inconsistent and were potentially to be degraded. Comparison of this method with field observation is shown respectively in Table 6. Inconsistency method delineated 12,660 ha (43%) out of 29,668 ha degraded land in Upper Citarum Catchment. Compared to scoring method, inconsistency method gave less accurate result.

Combination of Scoring Method and Inconsistency of Land Use (CSMILU)

Poorer result obtained using single Inconsistency of Land Use method, lead us to combine it with scoring method. Matrix distribution of degraded land obtained from combined inconsistency of land use and scoring method with field observation is shown in Table 7.

Combination of both methods was able to delineate corectly 21,693 ha (Group I) or 73% these degraded land (Table 7). Therefore, combination of scoring method and inconsistency increased the accuracy of degraded land delineation from 66% to 73% or about 7% (Table 8). Besides, combination of scoring method and inconsistency of land use provide other advantage in term of degraded land rehabilitation strategy. In scoring method, it was difficult to trace what biophysical parameter was responsible as the driving force for its degradation. Therefore, it was difficult to mitigate the most responsible cause, since the degree of land degradation was lumped in scoring value. In contrast to combination of scoring method and inconsistency of land use (CSMILU), the most responsible cause should be situated in LCC class VII and VIII. Graphical comparation of degraded land obtained by inconsistency of land use (CSMILU) and field observation (FO) in Upper Citarum Watershed is

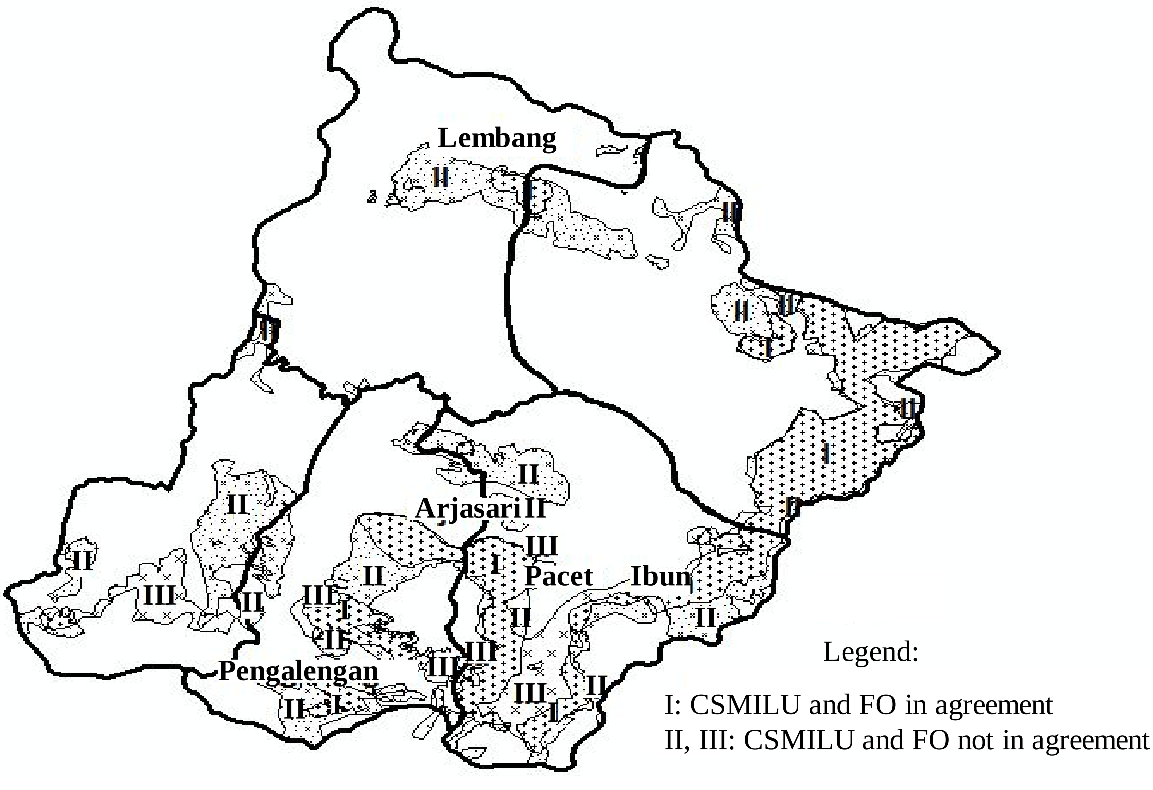

Figure 5. Graphical comparation of degraded land obtained by inconsistency of land use (CSMILU) and field observation (FO) in Upper Citarum watershed.

Table 8. Accuracy of different methods compared to field observation in delineating degraded land.

Type of methods	Accuracy (percentage)
Scoring method (SM)	66
Inconsistency of land use (ILU)	43
Combination of scoring method and inconsistency of land use (CSMILU)	73

shown in Figure 5. Group I identified areas where CSMILU and FO were in agreement. Meanwhile, group II and III showed areas where CSMILU and FO were not in agreement or misclassified.

CONCLUSIONS

Scoring method which is widely used in Indonesia to delineate degraded land throughout Indonesia was not accurate in particular areas. The method misclassified plantation area and terraced agriculture area as degraded land. The reasons were the un-proportional weight attributed to vegetation cover (50%) in the method. Certainly, if they were compared to forested area, plantation area and terraced agriculture area had less vegetation cover, but existence of good terraced preventing land degradation in the area. On a certain cases, scoring method misclassified degraded land as not degraded. These cases frequently occurred if agricultural areas were situated in class VII and VIII in LCC. No matter how good conservation measures and vegetation cover in these particular areas were, when they are utilized as agricultural area intensive degradation process will occur.

Alternative method proposed in this study which was the combination of scoring method and inconsistency of land use with the LCC (CSMILU) could increase the estimate on the degraded land up to 7%. Other advantage of alternative method compared to scoring method is the ability to identify the most responsible driving factor for land degradation, that is by locating inconsistency of land use.

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