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ASSESSING SOIL EROSION SEVERITY IN TEMPORAL AND SPATIAL PATTERN: A CASE STUDY IN THE PLEIKU PLATEAU, GIA LAI PROVINCE

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Abstract. Soil erosion is one of the major causes of land degradation and negatively impacts the soil environment in the world. There are two approaches to assessing soil erosion severity (SES) in terms of the decline of soil productivity in a given area: (1) classifying actual soil loss according to erosion risk classes, and (2) comparing actual soil loss to soil loss tolerance to classify erosion severity. This paper aims to explore changes in SES during 2005–2015 in the Pleiku Plateau, Gia Lai province, Vietnam, as a case study for comparing the two approaches. Regarding actual soil erosion, the average soil erosion rate declined by 0.16 ton/ha/year in the plateau terrain and increased by 0.02 ton/ha/year in the mountain relief. During 2005-2015, the low erosion risk area decreased by 6,302 ha, while the remaining erosion risk classes increased. With respect to soil erosion severity, the tolerable and moderate soil erosion acreages reduced by about 671.8 ha and 2,266.7 ha, respectively, and the high and severe ones increased; however, the severe soil erosion areas grew drastically. The differences between the two approaches come from consideration of the soil loss tolerance in assessing soil erosion severity. Thus, in order to assess SES for a region, comparing actual soil loss to soil loss tolerance provides SES indices that reflect the soil erosion problem, rather than only classifying actual soil loss. The findings are of enormous significance for environmental management, especially in addressing soil degradation.

Keywords: soil erosion, severity, tolerance, changes, land cover, Pleiku.

1. Introduction

Soil is a finite resource, resulting in two contradictory processes: soil erosion and soil formation. They are natural processes and are accelerated by human land management practices. Soil erosion is one of the most important land degradation issues, posing ecological and socioeconomic challenges [1]. About 35 - 50% of agricultural lands have been degraded by soil erosion in the world [2]. It led to significant economic as well as environmental degradation, both on-site and off-site. It is also one of the most serious threats to the sustainable development of agricultural ecosystems, especially in uplands. It causes direct impacts on sites, such as soil nutrient and crop yield reduction, which threatens food security. Annually, about 0.3% of agricultural gross outputs are lost to soil erosion [3]. Besides, it has an impact on lake and river sedimentation, which affects aquatic ecosystems, reduces reservoir capacity, increases maintenance costs, and decreases its lifespan. [4]. Both impacts influence soil quality, the global carbon cycle, biodiversity, and ecosystem services [5]. The main factors that affect soil erosion in a given area include rainfall erosivity, soil erodibility, slope length and steepness, cover management, and conversion practice factor.

There are two approaches to assessing soil erosion risk in relation to the decline of soil productivity in a given area: (1) classifying actual soil loss according to erosion risk classes, and (2) comparing actual soil loss to soil loss tolerance. According to the first approach, many studies have examined the effects of land use on soil erosion, such as Garcia-Ruiz (2010) [6], Tung et al. (2018) [7], Son et al. (2023) [8]. They indicated which land use caused high or low soil loss classes. In addition, considerable research has assessed soil erosion at different levels. For example, soil erosion was classified into five or three classes based on actual soil loss in Vietnam [7]-[9]. With respect to the second approach, there are some studies, such as by William et al. (2017) [10], Heidar et al. (2017) [11]. In order to assess SES in the Mississippi watershed, William et al. (2017) [10] calculated the difference between the adjusted actual soil loss (A) and the soil loss tolerance (T-value). Similar to William et al. (2017) [10], Heidar et al. (2017) [11] assessed soil erosion risk in the Haji-Ghushan basin, Iran, by comparing annual soil loss to the T-value; however, they calculated the erosion tolerance index (ETI) by the ratio of the T-value to actual soil loss to evaluate the on-site effects of soil erosion. Essentially, this index assesses the risk of soil erosion for a given area, particularly in upland agricultural and forestry ecosystems.

Each year, 100 million tons of soil in the Central Highlands of Vietnam are eroded and carried into the sea [12]. The primary cause identified is deforestation. The forest canopy decreased from 75% to 60% between 1985 and 2001. Among the factors affecting soil erosion, rainfall erosivity, soil erodibility, slope length, and steepness are considered difficult to change. In contrast, land conversion practices such as contouring and terracing to reduce soil loss by water are very effective, but they require high costs. Controlling soil erosion based on the cover management factor (i.e., making decisions on rational land use by farmers and managers) has been considered as feasible and effective, with appropriate costs [13]. According to Trinh (2015) [14], water-induced soil erosion has been a major cause of land degradation in the hilly and mountainous regions in Vietnam, and the Central Highlands is not an exception; the Pleiku Plateau in

Gia Lai province is one example. It is one of the most fertile plateaus in the Central Highlands with important industrial crops. Therefore, sustainable utilization of soil resources in the area is of decisive significance for the sustainable development of Gia Lai province. In fact, there have been few studies on assessing SES based on soil loss tolerance, and the comparison between these approaches has not been examined in Vietnam.

This paper aims to examine changes in the SES during 2005-2015 in the Pleiku Plateau, Gia Lai province, Vietnam, and compare the two approaches to assessing soil erosion severity. It is assumed that rainfall runoff erosivity, soil erodibility, slope length, and steepness were relatively stable.

2. Content

2.1. Methods and materials

2.1.1. Methods

**** Estimating actual soil loss***

Soil erosion is usually determined by two methods: direct measurement in the fields and estimation using models. In the world, the Universal Soil Loss Equation (USLE) has been used the most widely. [7], [10], [11], [15]. Equation (1), which was proposed by Wischmeier and Smith (1978) [16], has been applied in many studies on soil erosion in Vietnam, such as Anh (2017) [9], Tung et al. (2018) [7], Trinh (2015) [14], Nguyen et al. (2015) [17].

$$A = R \text{ x } K \text{ x } LS \text{ x } C \text{ x } P \qquad (1)$$

A: An average annual soil loss (ton/ha/year)

R: The rainfall runoff erosivity (MJ mm ha^{-1} h^{-1} $year^{-1}$)

K: The soil erodibility (ton ha^{-1} R $unit^{-1}$)

LS: The slope length and steepness (dimensionless)

C: The cover management factor (dimensionless)

P: The conversion practice (dimensionless)

- The rainfall runoff erosivity

Corresponding to a given study area, one experimental equation is used to calculate rainfall runoff erosivity. In 2017, Anh applied eq. (2) released by Pretl (1973) (cited by Anh, 2017 [9]) to estimate the R factor in Gia Lai province.

$$R = 0.058 \text{ x } P + 10.5 \qquad (2)$$

In order to determine the R factor for the Pleiku Plateau, eq. (2) was selected because of the rainfall regime in Pleiku.

- The soil erodibility

The soil erodibility factor (K factor) depends on soil resistibility to erosion, which in turn depends on soil texture, structure, and soil organic matter. In order to determine the factor, some researchers have used an experimental equation to calculate, such as Heidar et al. (2017) [11]. Another method of defining the K factor is estimation based on soil types [7] or a combination of soil texture and soil organic matter [17]. Due to limitations of soil analysis data, the K factor was estimated from soil types in the Pleiku Plateau according to MAFRC (2023) [18] (Table 1).

- The slope length and steepness factor

The LS factor depends on slope length and steepness, which affect soil erosion through surface runoff. Moore and Wilson's formulas [19] has often been used to calculate the LS factor.

$$LS = \text{Power}(\textit{Flow accumulation} \times \textit{Cell size} / 22.13, 0.6) \times \text{Power}(\text{Sin}(\textit{Slope of DEM} \times 0.01745 / 0.0896, 1.3) \quad (3)$$

The equation was also applied in this study since it had already been successfully used in the western part of Thua Thien Hue province, which is near the study area.

Table 1. The soil erodibility factor in the Pleiku

No	Soil texture	OM (%)	K
1	Silty loam	< 2	0.92
2	Silty loam	> 2	0.83
3	Clay loam	< 2	0.74
4	Clay loam	> 2	0.63
5	Clay	< 2	0.54
6	Clay	> 2	0.47

- The cover management factor

The factor considers the effects of land cover on soil erosion, and it is the most important factor in controlling soil erosion risk [20]. There are some methods to define the C factor. The first one is to assign C values based on literature reviews and available land cover/land use data, or by interpreting satellite images [15]. The second is to calculate them directly from the reflectance values of satellite images [7]. The C factor ranges from 0 to 1, where 0 represents lands without vegetation and 1 means lands with good vegetation cover. The study used the formula that was proposed by Durigon et al. (2014) [21] to calculate the C factor. The equation had been successfully applied in the western part of Thua Thien Hue province, too.

$$C = (1 - NDVI)/2 \quad (4)$$

- The conversion practice factor

The P factor reflects the effects of the support practices on soil erosion, such as contouring, strip cropping, and terracing. The P values range from 0 to 1, with 1 indicating the nonexistence of conservation practices and 0 indicating the presence of conservation practices. Among the above-mentioned factors, the P factor is the most difficult to estimate [22]. It could be estimated based on satellite images, expert evaluation, or literature reviews [7]. The P factor was assigned based on land use, slope data, and suggestions from the International Soil Science Congress (cited by Tuan, 2005 [23]) (Table 2).

Table 2. The conversion practice factor in the Pleiku

Slope (%)	Contouring	Terracing	Strip Cropping
1-2	0.6	0.30	0.12
3-8	0.5	0.25	0.10
9-12	0.6	0.30	0.12
13-16	0.7	0.35	0.14
17-20	0.8	0.40	0.16
21-25	0.9	0.45	0.18

**** Estimating the soil loss tolerance***

The determination of the T-value is one of the difficult issues in soil erosion studies [11] since it depends on soil formation. Data on soil formation are limited, and it is very hard to measure the soil formation rate at the boundary between soil and rocks [24]. Ten factors affect the T-value; however, two factors which were usually used to determine the T-value are the soil formation rate and productivity [25]. Some methods have been used to determine the T-value. However, the USDA-NRCS and the soil depth method have been applied quite widely in the USA and Australia [26]. With respect to the USDA-NRCS's method (1999) [26], the T-value was estimated based on the limitation horizon to plant roots. Soils were classified into 3 groups based on the limitations to plant root growth and soil productivity, and the T-value would be assigned according to the depth to the limiting layer.

In 2001, Baja et al. [27] proposed how to estimate the T-value based on soil depth. For soils with a thickness of above 1.5 m, the T-value would be assigned as 10 ton/ha/year, while for soils with a thickness of below 0.5 m, the T-value would be assigned as 1 ton/ha/year. For soils with thickness ranging from 0.5 m to 1.5 m, the T-value would be calculated using equation (5). In order to simplify, the Baja equation was used to estimate the T-value in Pleiku.

$$T = 9 \text{ x } D - 3.5 \tag{5}$$

where T: the soil loss tolerance (ton/ha/year), D: soil depth (m).

2.1.2. Materials

**** Study area***

The Pleiku plateau is one of the fertile basalt plateaus in the Central Highlands, Gia Lai province, Vietnam. It is located in coordinates of 16°30′N, 107°0′E and 16°0′N, 107°30′E (Figure 1). Its terrain is relatively undulating, with elevations of 600–800 m. It belongs to the tropical monsoon zone with two seasons: a dry season (XII – V) and a rainy season (VI – XI). The mean temperature ranges from 21 to 24 °C, and the average yearly precipitation is from 1.100 to 2.100 mm. There are 11 soil types and 6 land use types in the study area, of which Ferralsols and perennial crops (coffee, pepper) are dominant.

**** Data***

The data that were used to calculate the erosion factors include 4 Landsat images (Table 3) acquired in 2005 and 2015, a digital elevation model (DEM), rainy distribution data, and soil maps at a scale of 1:100,000 [28], and land use in 2005 and 2015 at a scale of 1:100,000 [29].

Table 3. The data from the Landsat images in the study area

No	Images	Day	Parth	Row	Sun Elevation	Earth-Sun distance
1	LC81240502015065LGN01	06/03/2015	124	050	55.83790812	0.9919089
2	LC81240512015065LGN01	06/03/2015	124	051	56.45769041	0.9919089
3	LT51240502005053BKT00	22/02/2005	124	050	50.19189167	0.9892139
4	LT51240512005053BKT00	22/02/2005	124	051	50.85522361	0.9892139

Source: USGS (2018) [30]

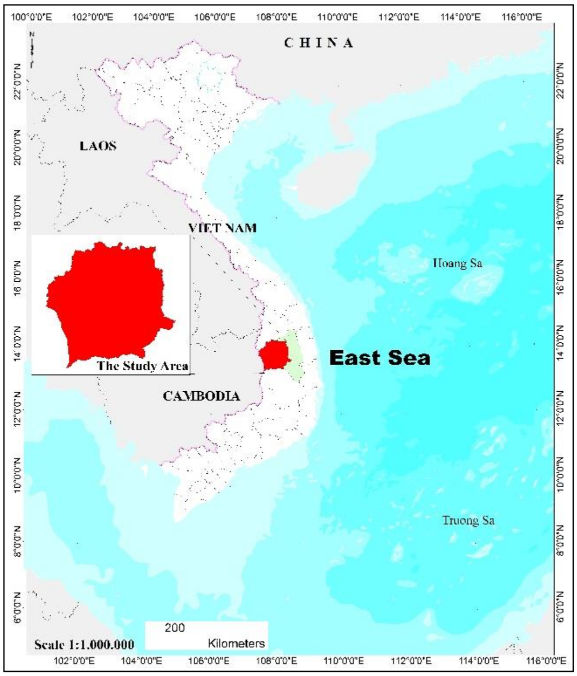


Figure 1. The study area in the inland

2.2. Results

2.2.1. The soil erosion factors

**** The relatively stable factors***

Due to the decreasing trends of average yearly precipitation from the central plateau to the southeastern region, the rainfall runoff erosivity (R factor) reflects the same trend (Figure 2). The land with an R factor above 100 (MJ mm ha^{-1} h^{-1} $year^{-1}$) occupies one-third of the study area.

As mentioned above, there are 11 soil types in the study area, of which Ferralsols are dominant, located in the central part of the plateau. Therefore, the soil erodibility factor (K) ranges from 0.47 to 0.92, and the K value that is more than 0.8 covers around 65% of the region (Figure 3). With respect to the slope length and steepness factor (LS), the highest values are distributed along the river valleys (Figure 4). The lands with the LS factor below 10 occupied more than 85% of the study area.

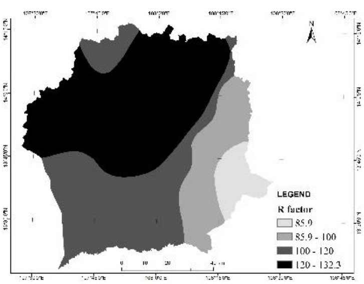


Figure 2. The R factor in the Pleiku

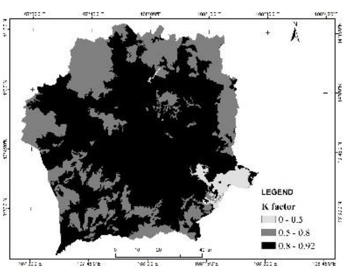


Figure 3. The K factor in the Pleiku

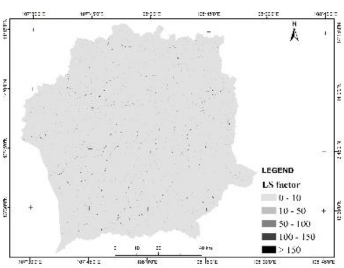


Figure 4. The LS factor in the Pleiku

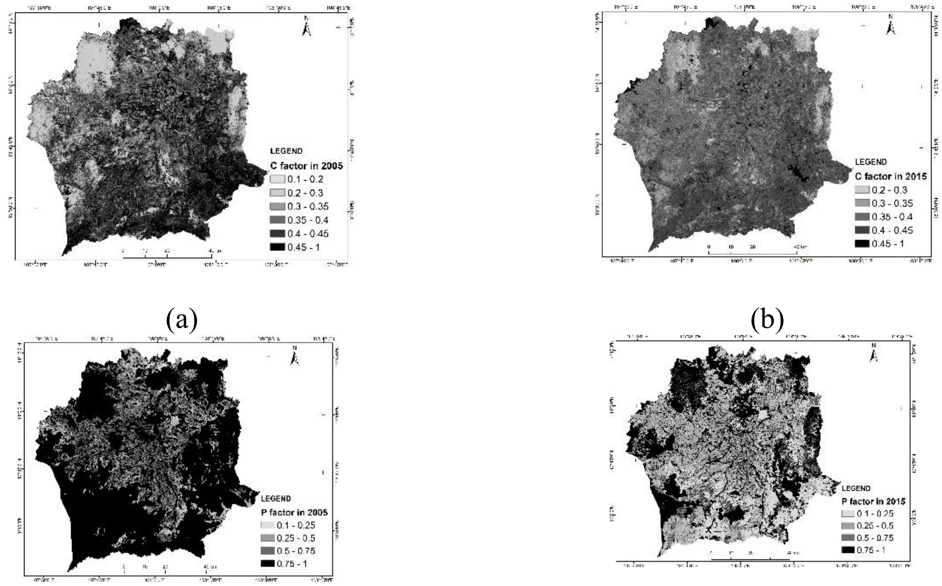
**** The changeable factors***

The cultivation extension and intensity in the plateau increased gradually from 2005 to 2015. Except for natural and plantation forests, the main crops cultivated in the plateau were coffee, rubber, pepper, and some food crops such as maize and paddy rice. Consequently, the cover management factor values in 2005 and 2015 were calculated from the Landsat images shown in Figures 5a and 5b. Lands with C values below 0.2 corresponding to NDVI above 0.6 decreased to zero, while lands with C values ranging from 0.35 to 0.4 corresponding to NDVI of 0.2 to 0.3, increased by 214 ha between 2005 and 2015. Lands with C values above 0.45, corresponding to NDVI below 0.1, increased by 980.5 ha. According to NASA (2000) [31], very low values of NDVI (0.1 and below) correspond to barren areas of rock and sand, moderate values (0.2 to 0.3) represent shrub and grassland, while high values (0.6 to 0.8) indicate tropical rainforests. Therefore, the results indicated that forest cover canopy reduced dramatically, while shrub and grassland areas increased remarkably during 2005-2015. It should be noted, however, that not all 178,989.6 ha were shrub and grassland because annual and perennial crops were not accounted for, as NDVI alone was used to interpret these objects. The conversion practice factor of less than 0.25 and above 0.75 decreased due to forest land reduction, and the conversion of some annual crop cultivating lands to perennial crops, while those ranging from 0.25 to 0.5 and from 0.5 to 0.75 increased (Figures 5c and 5d).

2.2.2. The actual soil erosion

The results of actual soil erosion in 2005 and 2015 are shown in Figures 6 and 7. The average actual soil loss in the Pleiku plateau was 19.82 tons/ha/year in 2005 and 18.58 tons/ha/year in 2015; this means that the soil erosion rate decreased. However, during 2005-2015, the average soil erosion rate in the plateau and mountainous terrain was -0.16 and +0.02 ton/ha/year, respectively. It reduced in the plateau relief and increased in the mountains. By land use types, the average soil loss rate in annual crops was the highest (0.79 ton/ha/year). For the natural forest, it was the lowest (0.05 ton/ha/year). With respect to other land use types, it was 0.11 ton/ha/year, 0.07 ton/ha/year, and 0.06 ton/ha/year in perennial crops, plantation forests, and shrubs and grass ecosystems, respectively.

Figure 8 indicates that low soil erosion (below 5 ton/ha/year) decreased by 6,301.9 ha from 2005 to 2015, while the other categories increased; for example, high erosion (10 - 50 ton/ha/year) and very high erosion (above 50 ton/ha/year) increased by 3,037.1 ha and 1,590.7 ha, respectively. Furthermore, high and very high soil erosion was concentrated in the mountainous regions in the northwest and northeast (the plateau edges). Low and moderate soil erosion was distributed mainly in the center of the plateau. The area in which low soil erosion changed into higher levels was 61,993.5 ha, and the reverse was 55,808.5 ha during 2005–2015. Therefore, the soil erosion increase was 6,185.1 ha higher than the decrease. Generally, the results indicate that soil erosion increased from 2005 to 2015 in the Pleiku plateau.



(a) (b)

(c) (d)

Figure 5. The cover management factor in 2005 (a), 2015 (b) and the conversion practice factor in 2005 (c), 2015 (d)

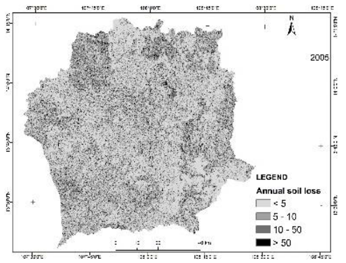


Figure 6. Actual soil erosion in Pleiku in 2005 (ton/ha/year)

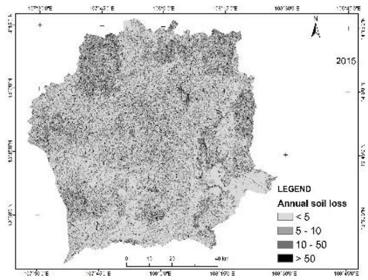


Figure 7. Actual soil erosion in Pleiku in 2015 (ton/ha/year)

Besides, in 2005 the calculation shows that for land cover with NDVI ranging from 0.4 to 0.6 and from 0.6 to 0.66, the percentage of high and very high soil erosion areas was the largest (29.72% and 28.77% of the land covers, respectively), followed by NDVI ranging from 0.3 to 0.4, from 0.2 to 0.3, and from 0.1 to 0.2 (all 25.2% of the land cover), and the last one being less than 0.1 (22.56%).

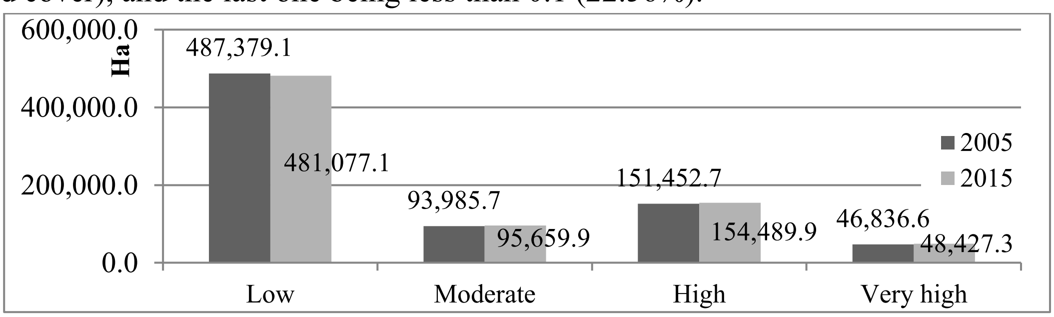


Figure 8. Changes in areas of the actual soil erosion classes in Pleiku during 2005 - 2015

Yet these values changed remarkably in 2015. For land cover with NDVI ranging from 0.4 to 0.6, the percentage of high and very high soil erosion areas got the highest value, 35.19%, followed by NDVI of 0.3 and 0.4 (31.23%), and NDVI ranging from 0.1 to 0.2 (23.06%).

The changes resulted from land use and decline of vegetative quality, especially forest land covers (Figures 9 and 10). Both figures indicate a conversion of 1,089.1 ha of land cover with NDVI above 0.6 (corresponding to tropical dense forest) into other land use types, increasing by 33.3 ha of very high erosion and 71.9 ha of high soil erosion. Notably, in 2015, the complete disappearance of land cover with NDVI above 0.6 showed degradation of the forest quality during 2005-2015 in Pleiku. This directly affected actual soil erosion in the regions because such land cover was distributed in mountainous areas. Interestingly, changes in land cover with NDVI from 0.4 to 0.6 (possibly open forest) had the greatest effects on soil loss in the area. Specifically, a decrease of 87,673.9 ha in this land cover resulted in an increase of 1,731.7 ha in the very high and 3,840.2 ha in high erosion classes.

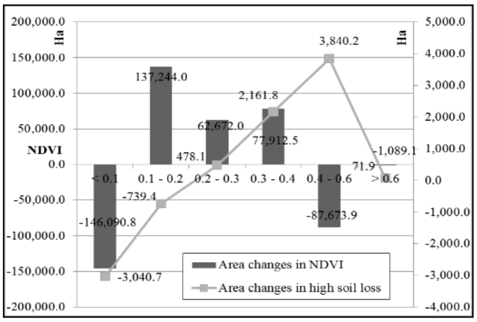


Figure 9. Relationship between area changes in NDVI and those in high soil erosion

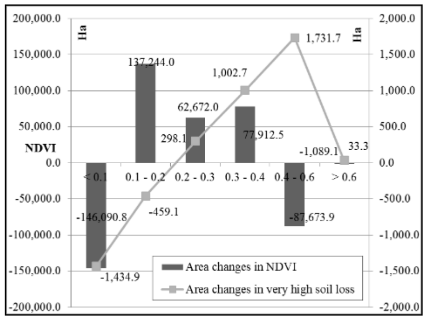


Figure 10. Relationship between area changes in NDVI and in very high soil erosion

It might be the impacts of the policy on the conversion of poor forest lands to agricultural lands, especially in the Central Highland of Vietnam. Subsequently, changes in land cover with NDVI ranging from 0.3 to 0.4 (maybe shrubs) were responsible for the increase in soil loss severity in the area. The areas of the high and very high soil loss classes were augmented by 2,161.8 ha and 1,002.7 ha, respectively.

2.2.3. The soil loss tolerance and assessing soil erosion severity

The soil loss tolerance, ranging between 5 and 10 ton/ha/year, was concentrated on Ferrasols in the central part of the Pleiku plateau (occupied 47,8%), and the values from 1 to 5 ton/ha/year were distributed adjacent to the plateau on Acrisols and some other soils (Figure 11). The Ferrasols mainly have soil depth above 1 m in the study area. In contrast, the thickness of other soils is often less than 1 m.

Figures 12 and 13 show the calculation results of the SES index in the study area in 2005 and 2015. On the tolerable acreages, it reduced by around 671.8 ha. Similarly, moderate soil erosion also decreased by 2,266.7 ha during 2005 – 2015, consistent with the actual soil erosion mentioned above. For the high and severe soil erosion lands, both areas increased; however, the severe soil erosion areas grew drastically.

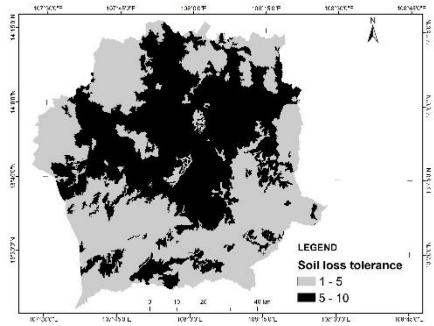


Figure 11. The soil loss tolerance in the Pleiku

Severe and high soil erosion was also distributed along the edge of the plateau, whilst tolerable and moderate erosion was concentrated in the center of the plateau, because high soil loss tolerance was also mainly located in the plateau center. Areas with SES moving into a higher level were 44,192.1 ha, while lands with SES changing to a lower level were 41,103.4 ha from 2005 to 2015. Consequently, the SES shows that soil erosion increased in the study area and stage.

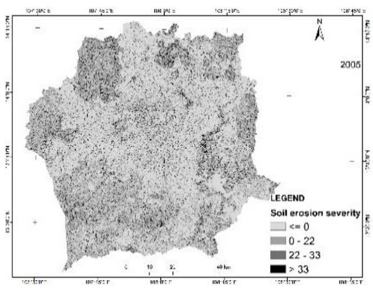


Figure 12. SES in Pleiku in 2005

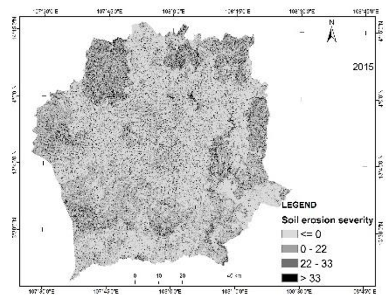


Figure 13. SES in Pleiku in 2015

The influence of the changes in NDVI on those in SES at the high and severe levels followed the same trend as the analysis of actual soil erosion (Figures 14 and 15). For instance, with respect to the changes in land cover with NDVI ranging from 0.6 to 0.66, a decrease of 1,089.1 ha resulted in an increase of 52.7 ha in severe and 18.8 ha in high soil erosion. For the changes in land cover with NDVI from 0.4 to 0.6, a reduction of 87,673.9 ha caused a large increase in severe soil erosion areas (2,618.5 ha), while the high ones were lower (997.4 ha).

2.3. Discussion

2.3.1. Soil erosion in the Pleiku

The average actual soil loss in the Pleiku plateau is approximately the same as in the A Sap river basin, Thua Thien Hue, in the central region of Vietnam [7]. With regard to the soil loss amount in 2015, lands in the low class (< 5 ton/ha/year) occupied the largest area (61.7 %), which was higher than that of Gia Lai province (54.6%). In contrast, lands in the high and very high classes accounted for 19.81% and 6.21%, respectively, which were smaller than those in Gia Lai province (23.5% and 10.2%, respectively) [9]. The reason is that the Pleiku plateau has relatively flat terrain, with parts of mountainous regions in the northwest and the northeast, whilst Gia Lai province includes the Pleiku plateau in the west and the Kon H Nung plateau in the east, with higher elevation and more intersected terrain. The interesting difference is that our study found high and very high soil erosion was distributed in the northwest and northeast of the plateau, while Anh (2017) [9] indicated that the erosion was concentrated mainly in the center of the plateau. The reason is that Anh (2017) [9] used land use data to assign the cover management factor. When using the data, he had not considered land cover quality. More specifically, for natural forests, the author just assigned low values (good vegetation) without considering the land cover canopy. Dense forests must be different from open forests. This has often been applied quite commonly in Vietnam and in the world, as by Anh (2017) [9] and William (2017) [10]. The study calculated the cover management factor directly from Landsat images through NDVI, which means that the land cover quality was considered. The findings suggest that satellite images should be used to estimate soil erosion to improve reliability.

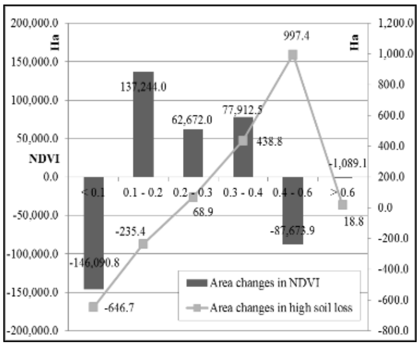


Figure 14. Relationship between area changes in NDVI and those in high SES

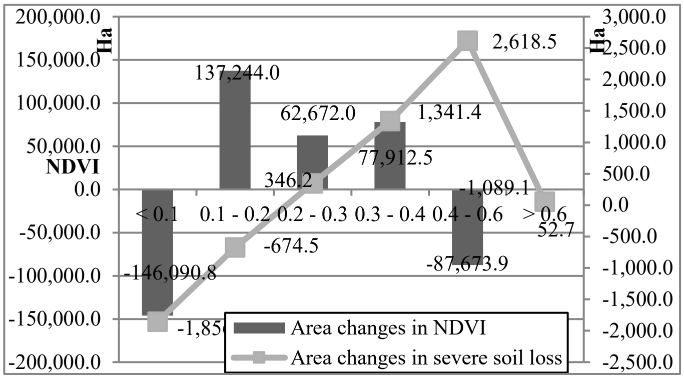


Figure 15. Relationship between area changes in NDVI and those in severe SES

2.3.2. Comparison of assessing soil erosion by actual soil loss and the SES index

As shown in Figure 16, for the tolerable, moderate, and severe soil erosion, their areas are larger than those of actual soil erosion (the low, moderate, and very high classes), while the remaining one has smaller areas. Additionally, the effects of changes in land cover during 2005–2015 on the SES showed the same trend as the analysis of actual soil erosion; however, the index indicated more serious soil erosion. For example, a decrease of 87,673.9 ha of land cover with NDVI from 0.4 to 0.6 led to a greater increase in the severe soil erosion regions than in the very high class. In 2005 and 2015, according to each NDVI class, areas of severe soil erosion were larger than those of very high soil erosion.

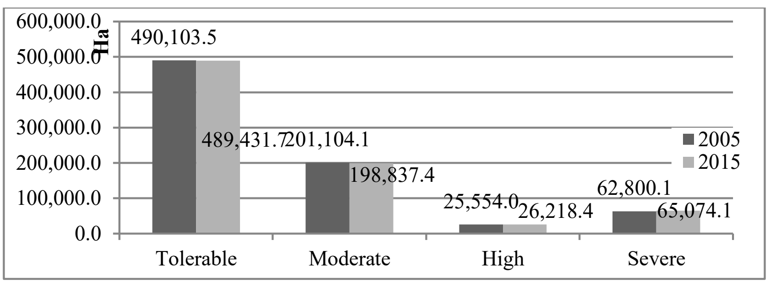


Figure 16. Changes in areas of SES in Pleiku during 2005 - 2015

The results indicate that assessing soil erosion using the SES index reflects the SES more clearly than the classification of actual soil erosion. This is because of two reasons. The first is that the SES index considers the soil loss tolerance of each soil. It means that acreages low in actual soil erosion were ranked, but it was able to be severe soil erosion based on the SES index because the actual soil loss was higher than the soil loss tolerance. The second is the intervals among classes, especially the classification of actual soil erosion. For actual soil erosion, the threshold value to define the very high soil erosion class is ten times larger than the one to determine the low class, while the range to quantify the high soil erosion class is from 10 to 50 ton/ha/year (five times), which is too large. For the SES index, the threshold value to define the severe soil erosion class is 33 ton/ha/year. The maximum soil loss tolerance is only 10 ton/ha/year; thus, the actual soil erosion corresponding to the value is 43 ton/ha/year. Furthermore, the range to quantify high soil erosion, which is from 22 to 33 ton/ha/year, is 10 ton/ha/year (once). The findings indicate that the SES index should be considered in environmental management.

3. Conclusions

The average soil erosion rate declined by 0.16 ton/ha/year in the plateau terrain, where it was concentrated in the center of Pleiku, and increased by 0.02 ton/ha/year in the mountains, where it was distributed along Pleiku's edge. During 2005–2015, the actual soil erosion increased, and the increase in soil erosion was 6,185.1 ha higher than the decrease. The changes resulted from changes in land use and the decline of vegetative quality, especially in natural forests. And the root cause was the policy of converting poor forest lands to agricultural lands in Vietnam. The soil loss tolerance, ranging from 5 to 10 ton/ha/year, was concentrated on the Ferrasols in the central part of the Pleiku plateau, and from 1 to 5 ton/ha/year was distributed adjacent to the plateau on Acrisols and some other soils. During 2005–2015, the tolerable and moderate soil erosion acreages reduced by about 671.8 ha and 2,266.7 ha, respectively, and the high and severe ones increased; however, the severe soil erosion areas grew drastically. In order to assess SES for a region in Vietnam and other regions, the usage of the SES index reflected the soil erosion problem more clearly compared to the application of actual soil loss classification intervals. It is necessary to consider soil loss tolerance when evaluating SES for a given area.

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