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論文内容の要旨

1. Background and objectives

Soil is an indispensable land resource for agriculture. High intensity rainfall events or drought happen more frequently due to progressing global warming. In addition, farming systems depending on agricultural chemicals threaten land resources, especially soil environment. Although there are many reports and studies dealing with land degradation, soil environment is still affected. El Jicaral Village in Mexico is also one of the areas where land degradation has been progressing.

Soil degradation processes are divided into three; physical, chemical and biological ones. Dominate factors that influence soil degradation processes are soil properties, climate, topography and vegetation. Soil properties are the parent materials and all those inherent properties of the soil, such as physical, chemical and biological properties. Concerning the climate, components that influence soil degradation are precipitation, temperature, evapotranspiration and seasons. Topographic components include slope, water systems and landscape position. Also vegetation components are related with biomass, biodiversity and succession.

There are several causes that produce soil degradation. Bio-physical causes are those related with land use, deforestation, farming systems, and crop and soil management. Also, socio-economic causes influence in soil degradation, such as ownership of the land, institutional strength, markets, poverty and health. In addition, the political causes are political stability and policies. Soil degradation is part of a descending spiral, where degraded soils are only capable to carry out subsistence agriculture, leading to poverty, including poor health and malnutrition, conducting to political instability, putting more pressure in natural resources.

Accordingly, this study dealt with the assessment methods for evaluating land degradation and the development of a soil conservation strategy that are applicable even in remote areas in developing countries.

2. Natural and agricultural conditions in research site

The research site for the investigation is located in Mixteca Region, which is one of the poorest regions in Mexico with land degradation and water scarcity situation. The Ministry of Environment and Natural Resources estimated around 500,000 hectares in the region presented high levels of land degradation in 1998. Mixteca Region is located in Oaxaca State in the southern part of Mexico with a surface of 15, 600 km^2 and around 450, 000 habitants.

The weather in Mixteca Region according to Koppen and Geiger is classified as Csb, which is for those areas with cool, dry summer and frost danger in winter. According to the National Meteorological Service, the average annual precipitation is of 1988.3 mm and the annual mean temperature is 15.0℃.

This chapter dealt with the assessment of the local farming situation of the research site. For this reason,

El Jicaral Village, that is in the second poorest municipality in Mexico with high levels of soil degradation located in the Mixteca Region, was selected for this study. Main crops are rain-fed corn, chilly and beans. Due to the uneven topography of the region, the upland fields, mostly situated in hillsides, are prone to land degradation process. In this village, questionnaire survey was carried out to local farmers.

3. Land degradation assessment in research site

Soil erosion represents the most extensive areas of degraded land worldwide, as more than 83% of the areas have been affected. In the classification of the land degradation, the processes of soil erosion dominated for rating the degree and extent of the land degradation. Based on this statement, land degradation assessment was conducted in El Jicaral Village based on the analysis of several variables observed on topographical maps and satellite images. The results of this assessment showed that more than 35% of the study area was under severe land degradation. To confirm the reliability and accuracy of the remote assessment, land degradation assessment was conducted by means of the field assessment. Accordingly, this chapter dealt with the evaluation of the viability of the land degradation assessment based on remote assessment compared with field assessment and to analyze the level of soil degradation in El Jicaral, Mixteca Region, Mexico.

Both remote and field assessments were done in the study area, on a mesh of 50 meters by 50 meters, covering an area of around 0.5 km^2. The results of land degradation assessment through the field assessment were compared with that through the remote assessment. In the field assessment, GPS was employed for clarifying the location in every cell. Then detailed observation was conducted based on '*Morgan Coding System*' with rating a value from 0 to 5 at the assigned cell. After obtaining a value based on '*Morgan Coding System*' for each cell, a comparison was done between the field assessment and the remote assessment. For comparison, statistical method using a correlation analysis was employed.

The results of statistical analysis indicated that there was a correlation between both assessments at 99% significant level. It means that the remote assessment based on several variables, such as steepness, slope, vegetation density and land use may be enough for assessing the land degradation in a small scale. This technique is useful when the land degradation assessment is necessary in small areas and not possible to conduct an on-site assessment.

According to the remote assessment as well as the field assessment through the survey in the research area, it may be concluded that El Jicaral Village is facing a serious land degradation process due to land use conditions in the village, such as crop cultivation under steep slope conditions, deforestation and cattle overgrazing. Furthermore, no soil conservation practices are conducted and chemical products are being used without understanding of their negative impacts. Due to these conditions, land degradation is a continuing process in El Jicaral Village.

4. Developing soil conservation strategy for Mixteca Region

The application of excreta wastes, an organic resource, is beneficial for soil conservation, especially in land degraded or being susceptible to erosion. Oaxaca State, Mexico, is the main state by numbers of goats (around 952,000 heads), which represents 10.9% of the national production. In this study, animal waste was used as a natural resource for protecting soils against erosion. So, this study dealt with the development of soil conservation strategy with animal waste slurry for mitigating soil loss in leptosol from Mixteca Region.

For this purpose, a splash erosion model and a surface runoff model were used. Raindrop model consisted in stainless steel cores of 1.0 cm long with inside diameter at 1.1 cm. Soil was placed inside at a dry density of 1.0 ± 0.1 g/cm^3. Fifty drops of artificial rain were dripped into the soil inside the core and soil loss was measured. On the other hand, slope model consisted of a plot of 91 cm × 3.15 cm × 1.4 cm, with a triangular cross section. Soil was filled in with the same dry density of raindrop model and 1.2 cm^3/s of deionized water was supplied during one hour on a 12 degree slope. Discharge was collected every ten minutes and soil loss was measured.

As a treatment for both models, animal waste slurry

was used. Horse dung was collected in the Horsemanship Club of Tokyo University of Agriculture and passed through a sieve at 212 μm in order to obtain slurry. Two treatments were set up ; animal slurry incorporated with soil, and crust formed with animal waste slurry. The oven dried mass ratio of soil to slurry was 66:1. Soil losses were compared among these 2 treatments. The results of splash erosion experiment showed that the addition of slurry decreased significantly soil loss rate from 6.4% to 1.3% for slurry incorporated cores and to 0.2% for formed bio-crust cores. The same tendency was observed in the surface runoff model experiment, where the application of slurry reduced significantly the soil losses from 558.6 g/m^2 to around 60 g/m^2 for both plots where slurry was added. Concerning the loss of nitrogen component, the results showed that significantly there was a higher release of nitrogen in the control plot than in the other plots where animal waste slurry was applied.

Therefore, it was concluded that the application of animal waste slurry was effective to reduce significantly soil losses by protecting the soil against kinetic energy of raindrops, as well as against shearing forces of surface runoff on at 12 degrees slope in leptosol soil of Mixteca Region.

5. Treatment of animal waste for elimination of *E. coli*

Although the application of animal waste slurry was effective for mitigating splash and sheet erosion, there is a risk of pollution for efflux of *E. coli* when applying animal waste slurry. For this reason, treatment for killing *E. coli* of animal waste was carried out. Air drying was conducted for animal waste slurry. After four weeks, the amount of *E. coli*, coliform bacteria and general bacteria was measured. On the fourth week, water content of slurry was 695%. There was neither *E. coli* survival, nor coliform bacteria in the slurry after four weeks of air drying. However, amounts of general bacteria 7×10^6 cfu/g survived.

The experiment was done in summer, the maximum temperatures was 36℃ during the experiment. However, usually harvest in El Jicaral Village is done around September, where the average temperature is around 16℃. For this reason, it is recommended to apply an increasing pH treatment, with the purpose of increasing pH to 9.0 and on doing so to kill *E. coli* and coliform bacteria. In Mexico, and particularly in local indigenous areas, where corn is the main product, there is a process call Nixtamalization that consists in boiling the corn in an alkaline solution, usually lime-water. So, it is recommended to use the residues of this process in the preparation of slurry.

6. Conclusions

This study dealt with land degradation assessment and soil conservation strategy that are applicable in Mixteca Region, Mexico. According to the land degradation assessment, it was confirmed that degradation is advancing in most of research site, with a sloping topography, shallow vegetation cover and which main land use was for upland farming. So, it is necessary to conduct soil conservation practices to ensure the future productivity of the farmlands.

For this purpose, the application of animal waste slurry was proposed as a soil conservation strategy in the research site, especially for mitigating the occurrence of soil erosion with kinetic energy of raindrops and shearing force of surface runoff. The results showed that the application of animal waste slurry reduced soil loss from 6.4% in control cores to 1.3% in slurry incorporated and to 0.2% in bio-crust formed. The same tendency was observed in the surface runoff model experiment, where the application of animal waste slurry reduced significantly soil losses from 558.6 g/m^2 to around 60 g/m^2 in both plots where slurry was added.

However, it was considered that there is a potential risk of pollution of water bodies due to the efflux of *E. coli* when applying animal waste slurry. So, air drying of slurry was conducted as a treatment to kill *E. coli*. It was found out that this treatment was effective with 0% of *E. coli* and coliform bacteria survival in the study case. For these reasons, it can be concluded that the air dried slurry application is an effective soil conservation strategy for mitigating land degradation in El Jicaral Village, Mixteca Region, Mexico.

審 査 報 告 概 要

この研究はメキシコの中でも最貧地域の一つで土地劣化が進行している Mixteca 地域 El Jicaral 村を対象としたものである。土地劣化の評価にあたっては，植生，地形，土地利用の 3 因子に基づきメッシュ法による重ね合わせによって評価（リモート評価）するとともに，現地では Morgan Coding System に基づいて 5 段階で土地劣化の程度を評価（フィールド評価）し，両評価手法において 99% のレベルで相互関連性があることを報告した。更に，El Jicaral 村における土地劣化の主要因は土壌侵食に起因したものであるため，現地の自然資源である家畜糞を活用した土壌保全対策について研究を進め，家畜糞スラリーの土壌への混合区のみならずクラスト形成区からの土壌および窒素成分の流出量はコントロール区を有意に下回り，土壌保全対策として有効であることを実証した。併せて，家畜糞スラリーの添加による大腸菌の拡散にも配慮し，大腸菌の移動についても追跡してその処理方法について議論を進めた。これら一連の研究成果はメキシコの中でも最貧地域の一つで土地劣化が進行している Mixteca 地域 El Jicaral 村で適用できる土壌保全対策を示した研究成果として評価した。

よって，審査員一同は博士（農業工学）の学位を授与する価値があると判断した。