Above/below ground ecosystems in Dambo (wetland) areas in Zambia

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I. Summary

English Summary (1 page)

This research aimed to investigate soil characteristics, soil insects and microbial communities and their potential changes due to the agricultural development in wetlands (Dambo). The soil samples were collected from cultivated (maize farms and watermelon farms) and uncultivated (native trees and grasslands) sites. Soil pH, EC and moisture was measured in Zambia. Soil insects’ diversity was also investigated at each sampling site by pitfall traps and tullugren systems. This research is still ongoing. I have already applied to the Japanese government for the permission to import some of the sampled soils for further analyses, particularly for soil microbiological data.

In future, after collecting soil animal/microbes data, small-scale soil animal/diversity map will be created. There were previous studies investigated the relationships between soil animal research and anthropogenic impact. However, in order to promote specific measures, it is important to develop of spatial information combining GIS data and soil animal diversity data.

The Dambo areas are often moist throughout the year and they are very important ecosystems in the sub-Saharan Africa. Thus, this project will enable local agricultural research sectors to evaluate what kind of soil animal/microbial/plant communities are suitable or unsuitable for agricultural development in the Dambo areas in Zambia.

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Host University and the period of my field research: University of Zambia, 2016/1/12~3/18
本研究は、ザンビアの湿地帯（ダンボ）における、農業開発による土壌動物および土壌微生物の多様性変化を調査することで、生態影響評価を行うものである。土壌サンプルは主に耕作地（メイズ、スイカ）と未耕作地（林、草地）から採取した。現地では、土壌 pH、EC、水分量を測定した。土壌動物の多様性については、ピットフォールトラップとツルグレンという方法によりそれぞれのサンプリングサイトで調査した。本研究は現在進行中であり、今後はザンビアから土壌サンプルを輸入し、さらなる化学的な土壌分析や土壌微生物群集構造解析を行う予定である。

これらのデータ収集後、本研究は小さなスケールでの土壌動物および微生物多様性マップを作成し、今後の持続可能な農業開発の提言をするための材料となるように発展させる。特にアフリカのような農業ポテンシャルが高いとされている地域で、その地域による具体的な環境保全対策を遂行するためには、地理的データと土壌サンプリングによって得たデータを結合した空間的情報に発展させていくことは重要である。

ダンボは一年を通して土壌水分が高く、サブサヘルアフリカにおいて特に重要な生態系が存在しているとされている。したがって、その貴重な地域においてサステイナブルな開発を推進していくことが重要だ。本研究によって、地元の農業開発部門に対して、どのような土壌動物・微生物・植物コミュニティが農業開発に適しているのかについて評価できるだろう。さらに、本研究の結果から生態学的視点から農業開発に適した地域を提案することも可能になるだろう。
II. Research Activity

1. Introduction

In Zambia, water resources are generally limited due to a short raining season. However, in wetland areas in Zambia, water is often abundant throughout the year. These wetlands are called “Dambo”. We believe that these areas can potentially be used as agricultural lands and the significant part of the Dambo area has been already cultivated. However, Dambo areas contain important natural resources, including plants, soil animals and microbes, but few studies have performed so far to investigate the changes in the natural resources due to the cultivation of Dambo areas, particularly in relation to the soil ecosystems. The relevant study shows that where Dambos dry out permanently, the plant composition markedly changed but the changes in the soil ecosystems have not been investigated [Burrough et al. 2015].

Thus, more studies are necessary for the investigate of the natural resources in Dambo areas and their potential changes due to the agricultural uses of Dambo area. This research aimed to investigate soil characteristics, soil insects and microbial community in Dambo area.
2. **Study Area**

   My field work was conducted in the area stretching between Lusaka and Kabwe, which is called "Chisamba" (14°59'S, 28°23'E) in Zambia. I sampled the soils from partly cultivated farm area. There were maize crops, watermelon and no agricultural area (native grassland and trees). Dambo areas are located around farmlands and cultivation is performed near the Dambos.

![Photo; no agricultural area (left) and watermelon farm area (right) in Chisamba](image)

3. **Methodology**

   **Soil sampling site and Experimental site of pitfall traps**

   Soil samples were collected from 10 sites, namely native tree sites (t), native grasslands (g), watermelon farms (w), and maize farms (m). Fig. 1 shows that each soil sample was different in color and texture (these will be investigated in future). Insect trap experiments were also conducted in the same area. Two traps were set up in “t” and “m” sites whereas four traps were set up in “g” and “w” area.

   ![Figure 1; There were various soil types.](image)

   **Soil Characteristic**

   Soil moisture contents were measured based on the dry soil weight after fresh soils were oven dried at 120°C for >24 hours. To measure soil pH, 10 grams of air-dried soils were mixed with 25 mL of water and shaken for 30 minutes followed by the measurement
using a pH sensor (HI98129, HANNA Co., Romania). In addition, inorganic-N (NO$_3^-$-N and NH$_4^+$-N), P and K will be analyzed in Japan.

**Soil Insects**

Soil insects’ diversity was investigated at each sampling site. To achieve this, “pitfall trap” systems were used. They can trap small insects crawling on soil surfaces. Traps consisted of a plastic cup containing a 70% ethanol to kill insects white plates covered the plastic cups to avoid rainfall to be trapped within the cup (Fig. 2). A "tullgren method" was also used to extract living organisms from samples of soil. Compared to pitfall traps, this method can catch smaller insects. In addition, Sticky sheets were used at the Dambo to catch flying insects (e.g. Aphids, White Flies, and Stink Bugs). All visible insects/soil animals were collection and categorized by using a camera and note in Zambia. The small insects will be divided at the order level (e.g. Beetles, Flies, Springtails, etc.).

![Figure 2; Photos of pitfall trap system. Traps consisted of a plastic cup containing 70% ethanol (left). After that, white plates cover the plastic cups (right)](image)

**Soil Microbial community**

To analyze soil microbes (e.g. Bacteria), DNA samples will be extracted from soils and will be analyzed using a next generation sequencer. This will be performed after we obtained the import permission from the Japanese government (under process). We aimed to obtain 16S rRNA based bacterial community structure data for each sampling site.

The data for soil animals and microbes will be mapped based on the GPS data thus we understand the controlling factors (e.g. distances from the water source) of the plant/soil animal diversities.
4. Research Findings

Soil Characteristic

Soil pH had, 5.75 ± 0.86, 5.51 ± 0.55, 6.38 ± 0.21 and 5.37 ± 0.21 for watermelon farms, maize farms, trees area and grasslands (no cultivation areas) respectively. All pH were less than 6 except trees area. Especially, the soil pH in watermelon farm was sometimes less than 5 (Fig. 3a).

Electric conductivity (EC) had, 43.5 ± 3.5, 69.5 ± 19.5, 45.5 ± 5.5 and 54.75 ± 45.2 for watermelon farms, maize farms, trees area and grasslands respectively (Fig. 3b).

Soil Insects

Fig. 4 shows some of insects sampled through the pitfall traps. Tulllugren methods showed smaller soil animals when compared to the pitfall traps. Fig. 4 shows that they are Tenebrionidae, Staphylinidae, Oligochaeta, Laccotrephes japonensis, DiplopodaI from upper left, respectively.

Figure 3; Soil pH(a) and EC(b) in soil measured for each land use

Figure 4; Photos of some of the insect by pitfall
Statistical analyses of soil animal community structures

To investigate the relationship between soil sampling sites (t, g, w and m) and soil animal data, the data were analyzed using canonical correspondence analyses. It is conceptually similar to principal component analysis, but applies to categorical rather than continuous data. In a similar manner to principal component analysis, it provides a means of displaying or summarizing a set of data in two-dimensional graphical form (Fig. 5). The signs “g”, “t”, “m”, “w” show land use types (g=grasslands, t=trees, m=maize farm, w=watermelon farm). Numbers mean the replication number. Capital characters mean each soil animal (Table 1).

Figure 5; Canonical Correspondence analyses between soil animals and land use. g, t, m, w shows land use types (g=grasslands, t=trees, m=maize farm, w=watermelon farm). Numbers mean the

Table 1; The soil animal information of Fig. 5
5. Discussion

I note that this research is still ongoing. My Japanese supervisor and I have already applied to the Japanese government for the permission to import some of the sampled soils for further analyses, particularly for soil microbiological data.

Natural diversity data map

The correspondence analyses show the effects of soil animal diversity by the land use change (Fig. 5). The soil animals sampled through the pitfall trap, such as *Lumbricina* (Earthworm) and *Geotrupidae* (Earth-boring dung beetle), mainly eat fallen leaves, feces and carcass. This means that the activities and numbers of these soil animals may influence soil organic matter accumulation, consequently soil fertility. These insects are known as indicators for the diverse soil animal communities [Ueda 2015]. *Caelifera* (Grasshopper) and *Staphylinidae* (Rove beetle) were mainly observed in the maize farm. On the other hand, there was no observation of the soil animals which decompose soil organic matter, such as *Lumbricina, Diplopoda* (Millipede) and *Geotrupidae*, in the maize farm. Thus, the maize farms might be lower in the soil organic matter contents when compared to the watermelon farms and to the no cultivation areas. Measurements of soil structure and the analysis of total carbon and nitrogen contents are need to further investigate the hypothesis and I will be performing these analyses when the soils are imported.

The g3 area was an uncultivated spot but was located on poorly drained soils, when compared to g1 and g2 sites and its soil animal diversity was similar to that of watermelon farm area (w1–3). It is difficult to fathom reasons for the similarity among w1–3 and g3 but factors such as crop type and/or soil drainage capacity may influence the magnitude of the effect of cultivation on soil animal diversities.

When compared to the watermelon sites and natural sites, maize cultivated areas had completely different soil animal diversity and the abundance of the species was smaller. This result may suggest that soil animal diversity was influence by maize cultivation but the influence of watermelon farming activities has to be investigated in longer term because the watermelon sites were relatively more recently cultivated.

In future, after collecting soil animal/microbes data, small-scale soil animal/diversity map will be created. There were previous studies investigated the relationships between soil animal research and anthropogenic impact. However, in order to promote specific measures,
it is important to develop of spatial information combining GIS data and soil animal diversity data.

Soil fertility

Generally it is though that African soil pH is low (acidic) and below optimum for the crop growth, and this assumption is supported by my study. Additionally, the EC was also very low for my site. The optimum EC value for crops is 200-400 μS/cm but my soils were all <100 μS/cm (Fig. 3b) [Kato 1996]. The EC indicates the total amount of the ion concentration of the various substances in soils and the values are related to soil fertility. Thus, the improvement of soil nutrients has to be achieved to increase the productivity of the site. During my stay, I observed that a lot of maize residues were piled and unused in villages. Farmers always threw them away after cultivation. In Japan, plant residues are often recycled on farm, some are returned as a charcoal. If these crop residues can be used to improve soil pH and EC status, soil fertility improvement can be achieved using locally available materials.

6. Conclusion

This project will help identifying soil animals/microbes living in the Dambo areas in Zambia and their potential changes due to the agricultural development. The Dambo areas are often moist throughout the year and they are very important ecosystems in the sub-Saharan Africa. Thus, this project will enable local agricultural research sectors to evaluate what kind of soil animal/microbial/plant communities are suitable or unsuitable for agricultural development in the Dambo areas in Zambia.

7. Acknowledgement

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8. References


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III. Reflection to the GLTP in Africa

Your motivation to participate in the GLTP

I had been interested in Africa region for a long time and wanted to go there someday. As I went on to university, transferred to the Faculty of Agriculture, and went on to graduate school, I came to learn a lot about agricultural problems of the world. When I faced with these global scale issues in relation to the future demand for food and its potential impacts on the environment, I began to think that Africa had an important role for the world in near future.

My purpose of this program was to see and to feel the current state of agricultural technology in Africa. Also, I wanted to research its potential impacts on the environment. My final goal is to help developing the foundation for future sustainable African agriculture.

Field experiences

Almost all of my Zambian research life was collecting/taking the photos of insects. However, I had an opportunity to visit some places and to know a lot of Japanese people living in Zambia. I also visited Zambia Agricultural Institute (ZARI). This institute is the largest agricultural research entity in Zambia. It has 10 research stations and the institutes’ overall objectives are to develop and adapt crop, soil and plant protection technologies and to provide a high quality, appropriate and cost effective service to farmers. Soil lab in ZARI has many kinds of machines. If these machines are used effectively for local farmers, they will be able to improve their farm managements.

Figure 6; One of the researcher and I at rice field in ZARI
In addition, I joined a resilience workshop in Lusaka. It was held in collaboration with Japanese Universities. The theme was “Climate Change, Agricultural Production and Nutrition: Towards Integrated Policy Design for Food Security”.

I also met a person who works for a trading company in Japan at the New Year celebration reception in the embassy of Japan in Zambia. We discussed about their crop project. We may collaborate as industry-university cooperation. He and I went to Chirundu area to observe the crop growth conditions and hold some meetings with farmers.

As stated above, I could get to know various places and people during my research. These experiences and connection are irreplaceable and precious things to me.

**Challenges**

In future, I would like to propose suitable areas for agricultural development, in relation to the ecological aspects in Zambia. However, doing ecological research means understanding very complex food chains and the ecosystems of insects or microbes which are very difficult. Also, crops’ disease causing mechanisms have to be further investigated in relation to soil animal/microbes.

Thus, my study aims to propose an eco-friendly farming methods without using excess pesticides but it is still difficult to identify the direct link among soil animal/microbial diversities and crop disease.

**How to make use of this experience to your future career development**

I have a plan to write a peer-reviewed paper after further analyses of the sampled soils. During my stay, I could meet a lot of Japanese in Zambia. These connections are still remaining strong even after I came back to Japan. I hope to develop my career to deal with issues related to African in the future.

**Encouragement to other students**

If you are interested in Africa, you have to apply for this program. This program can support your trip to Africa financially as well as let you have a chance to communicate with students with different backgrounds. Actually I was able to meet students from University of Tokyo and Kyoto University in Zambia thorough this program. However, this program does not include the fund to conduct a research. Thus it might be an issue for science students.