ラーニングクラスター2017 年
ハイスクール平和提言

Adaptation to Climate Change in Maize Production in the Sahel

サヘル地域におけるトウモロコシ生産の気候変動適応策

人権グループ

43 期　遠藤舞依、里内舞、川合勇一
44 期　黒田恵美

2015 年、国連で持続可能な開発目標（SDGs)が採択され、その 13 番目のゴールに、「気候変動に具体的な対策を」があります。気候変動の影響は地球規模で見られ、影響の種類も様々です。気候変動の影響をもっとも大きく受けている地域のひとつがアフリカサハラ砂漠の南に広がるサヘルと呼ばれる地域です。サヘルではトウモロコシが重要な主食の一種で、そのトウモロコシの生産量が気候変動によって 2050 年までに 12%〜40%下がると見られています。

気候変動への対策として主にミティゲーションと呼ばれる緩和策とアダプテーションと呼ばれる適応策の二種類があります。なかでも、地球規模の緩和策に比べ、より地域レベルでの対策が可能なアダプテーションに注目し、研究をしました。そして私達は、サヘルにおける農業の現状を改善する提案を作成するために、二つのリサーチクエスチョンを考えました。

1. サヘルのトウモロコシの生産はなぜ気候変動に対して脆弱なのか。
2. どのようなアダプテーションがサヘルの気候変動への対処に効果的か。

これらのリサーチクエスチョンをもとに、私たちは三人の教授にインタビューを行いました。そして、サヘルのトウモロコシ生産が気候変動に脆弱な原因には、トウモロコシ農業が雨水などの天然資源に頼っているということや不十分なガバナンスがあることが分かりました。また、適応策の一種である作物多様化については、現地の人々の食文化への影響があること、農業に利用するための気候変動シミュレーションモデルの情報が容易に現地の人々に手に入らないことを受け、現地の人々の食文化に配慮した注意深い作物多様化の実践と気候変動シミュレーションのデータを専用のスマートフォンアプリを作り、サヘルの人々に提供することを提案します。

Adaptation to Climate Change in Maize Production in the Sahel

In 2015, the United Nations released the Sustainable Development Goals as a successor to the Millennium Development Goals. SDGs include 17 goals, and the 13th goal is focused on climate change, which affects the environment in many ways. Although climate change may not appear to be a human rights' issue, it actually affects the right to access food, and the people in the Sahel are among the most influenced. This paper focuses on how Sahelian people can ameliorate the effects of climate change on maize production, their staple food, through agricultural adaptations.

Literature Review

Climate Change and the Sahel

Climate change refers to "a change in the usual weather found in a place" (Stillman, 2014). Climate change is happening all over the world, causing droughts, disturbing the regular climate and diminishing available lands for agriculture.

The Sahel is a region stretching over the southern Sahara Desert, crossing the countries of Senegal, Mauritania, Mali, Burkina Faso, Niger, Chad, Sudan, and Eritrea. The Sahel belongs to one of the driest regions on the globe, sub-Saharan Africa, and at the same time, one of the poorest. According to Africa Renewal Online (Harsch, 2017), in the Sahel, "Even in normal years, millions are in a permanent state of food insecurity." In fact, "nearly 25 percent of the world's malnourished population lives in sub-Saharan Africa" (Chu, 2017).

Maize as a Staple Food in the Sahel

Maize, or corn, is a staple food in the Sahel. Indeed, 50 percent of the population in sub-Saharan Africa consume maize (CGIAR, 2016). Also, maize cultivation covers nearly 17 percent of the estimated land in the sub-Saharan Africa (CGIAR, 2016). Sub-Saharan Africa

is the region where “more than 300 million people depend on maize, as their main food source” (Chu, 2017).

According to MIT News (Chu, 2017), “Maize is the most widely harvested agricultural product in Africa and is grown by small farmers who rely heavily on rainwater rather than irrigation.” Therefore, maize production in the Sahel is particularly susceptible to climate change, caused by the uncertain patterns of rainfall. Consequently, such effects of climate change will likely cause people in the Sahel to face serious hardships in food security.

Impact of Climate Change on Maize Production in the Sahel

As maize production in the Sahel greatly depends on precipitation, the uncertain rainfall patterns and droughts caused by climate change could easily reduce maize production in the Sahel. “Maize is a relatively drought-sensitive crop in a region where agricultural production is mostly rainfed (Chu, 2017).” If the world’s temperature rises by 2 degrees celsius by 2050, the maize production in the Sahel is expected to decrease by 12-40% (Ramirez & Thornton, 2015). Since maize is a staple food in the Sahel, this drop in maize production is likely to cause a great number of the population to suffer from possible food shortages. Therefore, their human rights would be violated because access to food would be denied due to climate change.

Mitigation and Adaptation

There are generally two main ways to tackle climate change: mitigation and adaptation. Mitigation refers to “an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2007).” That is to say, actions that reduce the world’s temperature, which is a major cause of climate change, will reduce the amount of greenhouse gas, such as CO2. These are crucial. Adaptation means “adjustment in natural or human systems to a new or changing environment (IPCC, 2001).” While mitigation addresses the fundamental cause of climate change, adaptation handles the possible damage or effects

caused by climate change. Since mitigation involves every country on a global scale, it is difficult to assess the effect of mitigation. Adaptation is more realistically important to make a significant impact since people in the Sahel are not large contributors to climate change and do not have enough power to deal with the damages. This paper focuses on local adaptation.

Adaptation Methods

Adaptation of agriculture is important in the fight against climate change so that the Sahelian people can obtain their right to food. There are various ways that adaptation can be employed in agriculture to alleviate the effects of climate change, and in this section, some of them are discussed.

One type is soil adaptation. Chemical adaptation can be used to develop soil fertility. The chart provided by the Alliance for a Green Revolution in Africa (Africa Agriculture Status Report, 2014) reveals the relationship between the adoption rate of four land management practices and the profits made by each in Sub-Saharan Africa. The land management practices were classified into four kinds: ISFM (Integrated Soil Fertility Management), organic input, fertilizer, and nothing (no adaptation). ISFM is a set of agricultural practices adapted to local conditions to maximize the efficiency of nutrients, water usage and to improve agricultural productivity. The first three practices of adaptation help to regulate climate change by increasing soil carbon over time. These produce more profits than doing "NOTHING (in other words, land without practices of adaptation of soil)." Therefore, soil adaptations not only led to profit, but also, to the growth of enough crops. In contrast, as shown in the chart, "NOTHING" makes the least profit of the four practices. In this way, adoption of chemical adaptation to the soil could be considered one of the most effective ways to withstand climate change. (Africa Agriculture Status Report, 2014)

Table 2.1 Adoption (%) and profitability (US$/ha/year) of soil fertility management practices in SSA

COUNTRY	ISFM	ORGANIC INPUTS	FERTILIZER	NOTHING
Mali	0	11	23	66
Uganda	0	68	1	31
Kenya	16	22	17	44
Nigeria	1	28	23	47
Malawi	8	3	52	38
Tanzania	1	3	1	95
Mali	18	37	16	27
	ISFM	**FERTILIZER**	**ORGANIC INPUTS**	**NOTHING**
Adoption rate (%)	6.2	19.1	24.6	49.8
Profit (US$/ha/year)a	36.5	24.6	15.1	10.4

(Africa Agriculture Status Report, 2014)

Simulation Model

Simulation model systems are another way of adaptation. Simulation model systems can forecast the future and help people make plans to prepare for the effects of climate change; information can be gathered regarding the harvest season or irregular weather patterns. Three models are discussed.

Global climate model. According to the Intergovernmental Panel on Climate Change (IPCC, 2013), the global climate model is a system that represents physical processes in the atmosphere, ocean, cryosphere and the land surface from increasing greenhouse gas concentrations. The system also considers crops, pests, weather and other influences.

Crop simulation model. The crop simulation model is a simulation system that estimates future yield of crops based on the climate condition through computer analysis. There are simulation systems at some institutions. For example, there are the Agricultural Production Systems Simulator, (APSIM Initiative, 2007), Cropsyst (Washington State University, 2017), and DSSAT (Hoogenboom, et al., 2017). Also, each of them are unique and are used in different ways, so they should be used with different applications in mind towards creating predictable scenarios (Yin & Struik, 2010).

Simulations lead by MIT.

The Food and Agriculture Organization (2017) has developed a crop model system called AquaCrop, which is a water-related crop model, and it authorizes everyone to utilize the modeling. Actually, the Massachusetts Institute of Technology has conducted a simulation of maize growth in the African fields by taking a multi model approach: a combination of a global climate model in an open-source crop model - Aquacrop (2017). First, they divided the continent into a grid pattern, with each grid cell measuring approximately 200 square kilometers and applied the crop model to simulate maize growth for each grid cell. Second, they input some information into each local grid, such as properties of the soil and the area of harvested crops in a given region. In the worst case estimate, the Sahel would experience widespread yield losses of up to 50 percent. It is necessary to consider multifaceted approaches to adapting climate change such as farm-scale changes: switching cultivars, expansion of irrigation and nutrient management, changes in planting dates, and increased institutional capacity like insurance programs, research support, and improvements in food transport (Dale, et al., 2017).

Research Questions

This paper seeks to illuminate what kind of adaptation is the most effective in the Sahel for the purpose of adjusting the maize production to climate change.

1. Why is maize production in the Sahel fragile to climate change?

This question seeks to answer why the Sahel region is especially fragile to climate change. Although climate change happens in many places on the earth, there are countries that are resilient to climate change. Also, some countries can rebuild quickly although they are damaged by climate change. Understanding what key factors determine resilience among

countries in the region would help suggest what kinds of adaptation methods are most effective for adjusting maize production in the Sahel.

2. What kinds of adaptation methods are effective to cope with climate change in the Sahel?

This paper has mentioned several adaptation methods used in maize production to climate change. However, since these adaptation methods are not enough, it is assumed that there are other effective types of adaptation to climate change in maize production. Therefore, this research further investigates other kinds of adaptation methods.

Methodology

Research Question 1

To analyze the Sahel's vulnerability, several actions were undertaken, which involved doing further literary research, and conducting interviews.

First, a report entitled, *"Beyond Any Drought,"* (Trench, et al, 2017) published by the International Institute for Environment and Development (IIED), was investigated more deeply since it discusses issues that are covered in this paper.

Second, from October 7th to October 19th, 2017, an email interview on climate change and adaptation methods was conducted with Shinjiro Sato, professor of the Department of Environmental Engineering for Symbiosis at Soka University, Hachioji, Japan. The interview was conducted in order to assess the relationship between adaptation methods and maize production in the countries of the Sahel. The following two questions were submitted seeking to uncover better adaptation methods and to assess the effectiveness of a diversification of crops, which we assumed would contribute to reducing the heavy dependence on maize in the Sahel.

Q1. Aside from soil adaptation, what kind of effective adaptation methods for maize production exist?

Q2. Is the realization of a diversity of crops practical in the Sahel?

Third, on November 4th, 2017, email interviews on climate change and adaptation methods were conducted with Mr. Yasuaki Hijioka, Head of the Regional Environmental Impact Assessment Section of the National Institute for Environmental Studies, Ibaraki, Japan and with Professor Yuji Masutomi, professor in Earth Environmental Studies at Ibaraki University, Japan. They were both asked the same three questions. These interview were conducted in order to assess the effectiveness of climate-change scenario models as an adaptation method in the Sahel and to seek further adaptation methods for maize production in the Sahel. The following three questions were submitted:

Q1. Does the promotion of model systems in the Sahel contribute to raising the adaptability of maize production to climate change?

Q2. How does the information generated by model systems reach and apply to the people in the Sahel?

Q3. What kind of adaptation method do you think is suitable for the environment in the Sahel?

The results of these interviews are reflected in the suggestions offered in the proposal section of this research on how people in the Sahel could adapt maize production to climate change.

Results

Research question 1 asks why maize production in the Sahel is fragile to climate change. The report entitled, *"Beyond Any Drought,"* which explores the reasons of vulnerability in Mali, is instructive. The report categorizes the reasons into four

groups-agro-climatic, governance, trade and markets, and for other reasons. As can be seen in the chart from the report, there are many factors that impact the vulnerability of a country to climate change. Basically, the reason the Sahel is vulnerable is because of its dependence on natural resources, poor access to services and weakness from decentralization.

Agro-climatic	Governance	Trade and markets	Other
• Drought/Irregular rain	• Political marginalization	• Exchange rate of US Dollar/Euro	• No proper study on vulnerability has been done
• Climate	• Poor management of emergencies	• Oil price	• Lack of technical knowledge
• Lack of land available for cultivation		• World markets in rice, cotton, wheat	• Breakdown of family
• Low production		• Perverse interventions in cotton	• Continued pauperization
• Locusts		• Subsidies that pervert prices	• Vulnerability differs from zone to zone
• Inadequate/poor water management		• Unstable markets in grain and livestock	• Structural forces
• Types of production practised		• Inadequate mechanisms for moving food to permanent deficit areas	• Insecure land tenure (poor excluded from ownership).
• Extensive monoculture		• No transformation in Mali but export of raw materials	• Difficult access to credit
			• Absence of agricultural insurance

(Beyond Any Drought, 2017)

Interview with Professor Sato

Question 1: Aside from soil adaptation, what kind of effective adaptation methods for maize production are there? He said that “I think we can promote a variety of improvements. In fact, a variety of new breeds that are resistant to the dry climate. Also, there are breeds that are resistant to high humidity.”

Question 2: Is the realization of a diversity of crops practical in the Sahel? He answered that, “I think the idea of changing the staple diet of the people in the Sahel is not very practical. Food culture can be considered almost the same as identity. Still, the diversification of crops can probably help the Sahelian people in difficult circumstances. For example, when maize production is severely damaged, a variety of food could work as a complementary diet to prevent poverty and hunger. When promoting the diversification of

crops, it is important to ensure that the crops can be incorporated into the environment of the Sahel in terms of the environment, the financial situation, the technological situation, and the availability of human resources. The crops will not necessarily be accepted by the residents in the Sahel. It may not be easy to modify the diet of Sahelian people."

Interview with Professor Hijioka

Question 1: Does the promotion of model systems in the Sahel contribute to improving adaptability of maize production to climate change? Mr. Hijioka answered, "I think it is possible to introduce technology from developed countries to developing countries, and they can benefit from the established system. However, in general, model systems often include errors: the predicted result may not match the real situation. Therefore, they need to adjust model parameters using observational data, or improve the model systems. Since expertise is required to implement the process, only experts could cope with the situation and obtain the needed information."

Question 2: How does the information generated by model systems reach the Sahelian people and how can it be applied to their circumstances? He said, "Unless the data is provided freely, it is mostly provided through international organizations or governments. When trying to provide information for Africa, establishing a framework is necessary. Research results are often published in papers or reports, but they are not provided as digital data, which makes it hard for those who hope to actually use the data."

Interview with Professor Masutomi

Question 1: Does the promotion of model systems in the Sahel contribute to improving adaptability of maize production to climate change? He said that "I think the introduction of model systems could effectively reduce the fragility to climate change. There are two main roles of modeling systems: to know the future effects of climate change and to

analyze the cause of the effects. As for the disadvantages of model systems, it can forecast incorrectly. Therefore, it is important to recognize the uncertainty of model systems."

Question 2: How does the information generated by model systems reach the Sahelian people and how can it be applied to their circumstances? He stated that "so far, the anticipated results have usually been published in papers only, but I suppose the current trend of using the Internet will gradually improve the accessibility to the data."

Question 3: What kind of adaptation method do you think is suitable for the environment in the Sahel? He stated that "for droughts, introducing irrigation and a strong varieties of crops to contend with a dry climate might be effective. For floods, constructing dams and introducing these tough varieties might be efficacious to withstand floods.

Discussion

This section discusses the findings from the results in terms of each research questions.

Research Question 1: Why is the maize production in the Sahel fragile to climate change? In the paper, *"Beyond Any Drought.*" the vulnerability of the Sahel caused by many factors. One of the biggest reasons is climate change. Recent irregular rain patterns and drought affect agriculture in the Sahel. Furthermore, 70-80 present of the population is too dependent on natural resources, so it makes them more vulnerable. As for the weakness in governance, emergency management is very poor and there is also corruption, so it makes the situation more difficult to overcome.

Research Question 2: What kinds of adaptation methods are effective to cope with climate change in the Sahel? Professor Sato suggested that it is possible to promote the

plantation of breeds that are resistant to dry or wet climates for those who find it difficult to access food because of climate change. This can be a good adaptation of agriculture.

Professor Sato also emphasized that the introduction of crop diversification should be discussed well because the Sahelian people already have their own culture of food. It is necessary for us to comprehend the historical culture of food as well as the agricultural aspects. He thinks that culture should be given priority since the food culture is closely connected to the identity of the local people, and if the situation is carefully considered, then it may be possible to promote a diversity of crops.

Both Professor Masutomi and Professor Hijioka agreed with the idea of introducing model systems. However, Professor Hijioka mentioned that model systems often include errors such as when a predicted result did not match the real situation. Hence, it is necessary to adjust the model parameters using observational data, or improve the model systems. His cautious observation provided us an important perspective. Technology is not perfect. People need to be careful when they use model systems. Therefore, thinking carefully about the advantages and disadvantages of such systems is necessary.

Both Professor Masutomi and Professor Hijioka expected that the local people could not easily access the information from the calculations provided by the model systems. The reason for such a difficulty is that the information is not generally accessible as digital data, but rather found in reports or papers. Thus, the people cannot work with the data effectively. For that reason, the data generated by the systems is still not applicable toward climate adaptation for the Sahelian people. To improve the situation, Professor Masutomi mentioned that it would be useful to digitize this information and make it accessible to all people through various applications on their electronic devices, such as mobile phones and computers, in the near future.

Professor Hijioka suggested some adaptation methods for droughts and floods. The methods he suggested were to introduce other crops which can tolerate climate change. However, as Professor Sato noted, given the difficulty of introducing other crops as staple foods, it is important to consider the culture of the people in the Sahel in order to successfully implement the diversification of crops.

Proposal

Based on the research in this study, two suggestions are offered.

First, it is necessary to implement a diversification of crops with deep respect to Sahelian people's food preferences. This should be considered seriously. In countries of the Sahel, people also produce rice, millet and so on, which are considered common foods as well as maize. This indicates that it might be possible to consider other food besides maize in such countries. Through promoting diversification of crops, it is important to respect their existing food culture, so we think deep discussion with Sahelian people is very important.

Second, the creation of new applications for cell phones that can visually show how the climate will change in the future should be created to enable Sahelian people to easily access the information calculated by model systems. Since the information calculated by simulation models is usually shared through papers or reports, it is not very accessible by ordinary people. Also, the app can provide agricultural strategies such as how to effectively use fertilizer, farming machines, and report on market fluctuation news and stock information. One of the main causes of chronic vulnerability is that farmers cannot acquire the necessary knowledge to make adaptations in their production. Given the rapidly rising penetration rate of cell phones in the Sahel, introducing applications would help the Sahelian people to adjust maize production to climate change. For instance, the number of cell phone subscribers in Senegal exceeded 99.9 % of the population. Moreover, the rate of people who make phone

usage contracts is 139.6% of population in Mali. On the other hand, some countries in the Sahel such as Niger (46.5%) and Eritrea (7.0 %), do not have so many people who use cell phones. This is still room for improvement. Therefore, we should consider the possibility of sharing these possibilities thoughtfully, and encourage the use of applications to help manage productive agriculture.

Limitations

Although we hoped to discover the reasons why some countries are fragile or strong toward climate change from the beginning, we could not obtain enough information to determine the factors differentiating certain countries from others in terms of resilience to climate change. Examining differences such as financial factors and harvesting areas more concretely would be needed to determine the exact nature of vulnerability. Also, due to time constraints, we could not survey many experts in the field. More interviewers would have further helped us find more methods and reconfirmed the effectiveness of the methods suggested in the proposal section.

Conclusion

This research sought to uncover what kinds of adaptation methods can help Sahelian people to survive the severe effects of climate change through agricultural adaptations. Climate change is not someone else's problem, it is a problem shared by everyone on this planet. People might not recognize that they are unconsciously violating the human rights of people on the other side of the world. To realize this shared responsibility might be the first step to take. Adaptation is the key to protect the human rights of the people in the Sahel.

References

Alliance for a Green Revolution in Africa., (2014). *Africa Agriculture Status Report*. Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/agra-africa-agriculture-status-report-2014.pdf

APSIM Initiative., (2007). Agricultural Production Systems Simulator. Retrieved from http://www.apsim.info/AboutUs.aspx

CGIAR., (2016). Why Maize. Retrieved from http://maize.org/why-maize/

Chu, J.,(2017). Climate change to worsen drought, diminish corn yields in Africa. *MIT News*. Retrieved from http://news.mit.edu/2017/climate-change-drought-corn-yields-africa-0316

Dale, A., Fant, C., Strezpek, A., Lickley, M., Solomon, S. (2017). Climate model uncertainty in impact assessments for agriculture: a multi-ensemble case study on mizen sub-saharan Africa. *Earth's Future, 5*, 337-353. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/2017EF000539/epdf

Food and Agriculture Organization of the United Nations. (2017). AquaCrop. Retrieved from http://www.fao.org/aquacrop/software/aquacropstandardwindowsprogramme/en/ http://www.fao.org/3/a-i7179e.pdf

Harsch, E., (2017). A New Face of the Sahel. *Africa Renewal Online*. Retrieved from http://www.un.org/africarenewal/magazine/august-november-2017/new-face-sahel

Hoogenboom, G., C.H. Porter, V. Shelia, K.J. Boote, U. Singh, J.W. White, L.A. Hunt, R. Ogoshi, J.I. Lizaso, J. Koo, S. Asseng, A. Singels, L.P. Moreno, and J.W. Jones. (2017). Decision Support System for Agrotechnology Transfer (DSSAT) Version 4.7. DSSAT Foundation, Gainesville, Florida, USA. Retrieved from https://DSSAT.net

IPCC, (2001). Climate Change: Synthesis Report. Adaptation. *Annex B. Glossary of Terms*. Retrieved from http://www.ipcc.ch/ipccreports/tar/vol4/index.php?idp=204

IPCC, (2007). Differences, similarities and complementarities between adaptation and mitigation. *IPCC Fourth Assessment Report: Climate Change 2007*. Retrieved fromhttps://www.ipcc.ch/publications_and_data/ar4/wg2/en/ch18s18-1-2.html

IPCC, (2013). Climate Change 2013: The Physical Science Basis. Retrieved from http://www.ipcc.ch/report/ar5/wg1/

Pippa Trench, John Rowley, Marthe Diarra, Fernand Sano, Boubacar Keita (2017). *Beyond Any Drought*. Retrieved from https://reliefweb.int/sites/reliefweb.int/files/resources/F43A31DC485EF113C12573150037215B-Full_Report.pdf

Ramirez-Villegas, J., Thornton, P.K. (2015). Climate change impacts on African crop production. *CGIAR Research Program on Climate Change, Agriculture and Food Security.* Retrieved from https://cgspace.cgiar.org/bitstream/handle/10568/66560/WP119_FINAL.pdf

Stillman, D., (2014). What Is Climate Change? *NASA Knows*. Retrieved from https://www.nasa.gov/audience/forstudents/k-4/stories/nasa-knows/what-is-climate-change-k4.html

Washington State University, (2017). Cropsyst. Retrieved from http://modeling.bsyse.wsu.edu/CS_Suite/cropsyst/index.html

Yin, X., Struik, P. (2010). Modelling the Crop: From System Dynamics to Systems Biology. *Journal of Experimental Botany*. Retrieved from https://academic.oup.com/jxb/article/61/8/2171/486652/Modelling-the-crop-from-system-dynamics-to-systems