Republic of Indonesia
PT. Perkebunan Nusantara X (Persero)

Republic of Indonesia
Collaboration Program with the Private Sector for Disseminating Japanese Technology for
Synthesized Sensing Technologies for Enhancing the Agricultural Productivity

Final Report
Summary

May 2016

Japan International Cooperation Agency (JICA)

NEC Corporation

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Executive Summary

I. Collaboration Program

- "Collaboration Program with the Private Sector for Disseminating Japanese Technology" is a JICA's public-private partnership program which aims to demonstrate Japanese enterprises' technologies that respond effectively to specific development challenges.

II. Current Situation and Issues of the Sugar Agriculture

- The consumption amount of sugar will increase, so that production increase of the sugarcane and departure from the import dependency are the urgent issues.

III. Technologies and Results

   a. Agricultural Remote Sensing Technology

- The effectual satellite images were acquired, which proves it possible to grasp over the large field the progress of cultivation work (such as harvesting the sugarcane and planting etc.) and the growth situations at the early stage.

- As for the target crop (Sugarcane), the difference of vegetation index corresponds to the difference of growth situations confirmed on the ground, which proves that agricultural remote sensing is usable.

- By analyzing the causes of the bad growth situation (for soil, fertilizing, water, pest and disease etc.), indications of improvement are expected to be obtained.

   b. Agricultural Meteorological Data Analysis Technology

- By continuously monitoring the meteorological factors through the year, the meteorological characteristics of the rainy season and the dry season were recognized. Those meteorological data that will affect the production amount and quality of the sugarcane (solar radiation amount, rainfall amount, temperature difference per a day) can be obtained.

   c. Positioning Satellite Application Technology

- By utilizing this system, those tasks like the cultivation planning, progress monitoring, harvest planning, production analysis outputting, and improvement planning can be facilitated.

IV. Conclusion

- By utilizing the agricultural remote sensing technology and agricultural meteorological data analysis technology, the basic platform were built, which enables monitoring the growth situations over the large area, under the conditions of various cultivations (breed variety, seeding timing, cultivation method etc.) as well as of the various meteorological factors (temperature, rainfall amount, solar radiation amount etc.). .

V. Suggestion for the further collaboration

- 1st STEP is to execute the demonstration of integrated solution, which facilitates giving the proper instruction to the field workers at the proper timing, as well as facilitates

analyzing the outcome of harvesting/sugar milling, making the improvement plan and diagnosing its effectiveness through monitoring the progress of implementation of this improvement plan.

- As the yield prediction is expected, high level of sensing technology, further data accumulation and analysis shall be implemented.
- The project shall be implemented as the joint pilot project of PTPN-X and NEC with the farm scale of 10,000ha. In this way, both parties build the model case of advanced ICT agriculture in Indonesia as well as execute the capacity building to create the unique intellectual property right.
- 2nd STEP is to expand the agri ICT technology to the whole of contracted farmers of PTPN-X (80,000ha). Currently PTPN-X is rendering the technical assistance to the contracted farmers, so that it will be efficient to utilize this scheme to expand the technology.
- For these steps, we would like to propose utilizing the ODA program for the purpose of disseminating and enrooting the Japanese ICT technology into the sugar agriculture in Indonesia.

1. Collaboration Program Outline

1.1 Background

In MP3EI, Indonesian government set up the goal to transform the nation into "global base of the food security", placing 5 items of the rice, cone, soybean, sugar and beef as the target items to be intensively increased. However, currently, national production capability is deficient for satisfying the domestic demand. Therefore, increasing these items is urgent issue.

Among these, sugarcane agriculture of Indonesia has the issue that the domestic consumption of sugar depends on importing from the other countries like Thailand while the sugar demand is increasing according to improvement of living standards of Indonesia. The volume of the imported sugar in the past 20 years increased to 13 times, and currently Indonesia is the 2nd largest sugar importing country in the world. Under these situations, the agricultural technology of making full use of sensing technology, which is able to cover the large farm field, is effective and efficient as the means to improve the agriculture in the nationwide scale, and is expected to contribute to increasing the sugar production (improve the self sufficiency), the income of the sugar farmers, and production of bio ethanol.

In this project (program), having PT. PERKEBUNAN NUSANTARA X (hereinafter called "PTPN-X"), the state-owned and largest sugar mill/plantation company in Indonesia with considerable number of the contracted farmers, as the implementing organization, their understanding about our technology shall be promoted by introducing agricultural sensing technology, as well as the utility for the development of agriculture shall be investigated.

1.2 Target Area and Beneficiaries

Target Area: Kediri Prefecture, East Java

Beneficiaries:　・PTPN-X

　　　　　　　　・Farmers contracting with PTPN-X for sugar refining

1.3 Technology to Be Disseminated

Figure 1 shows the concept of our comprehensive agricultural support program. Synthesized sensing technology is the technology to grasp and manage comprehensively, by using ③Geographical Information System(GIS), the various data of the farm field conditions, which are collected by ①Earth observatory satellite system and ③meteorological sensing system etc. In this project, we term ① as "Agricultural Remote Sensing Technology", ② as "Agricultural Meteorological Data Analysis Technology" and ③ as "Positioning Satellite Application Technology".

A use case of this technology is as below:

· Through analyzing the various data, to facilitate finding the co-relations between meteorological factors, harvesting work and growth situation.

· To facilitate making plan timely and taking action timely for cultivation, harvesting, and stabilizing the operation of sugar mills.

· To facilitate giving the proper instruction to the field workers at the proper timing.

· Through analyzing the outcome of the harvesting and sugar milling, to facilitate making the next year plan for planting , and coming up with improving plan for the cultivation method as well as for harvest transportation.

· To monitor the progress and result of improving plan and assess its effectivity.

As mentioned above, agricultural comprehensive support program provide a strong support for continuously improving the agricultural technology and know-how, which in turn will enhance the productivity.
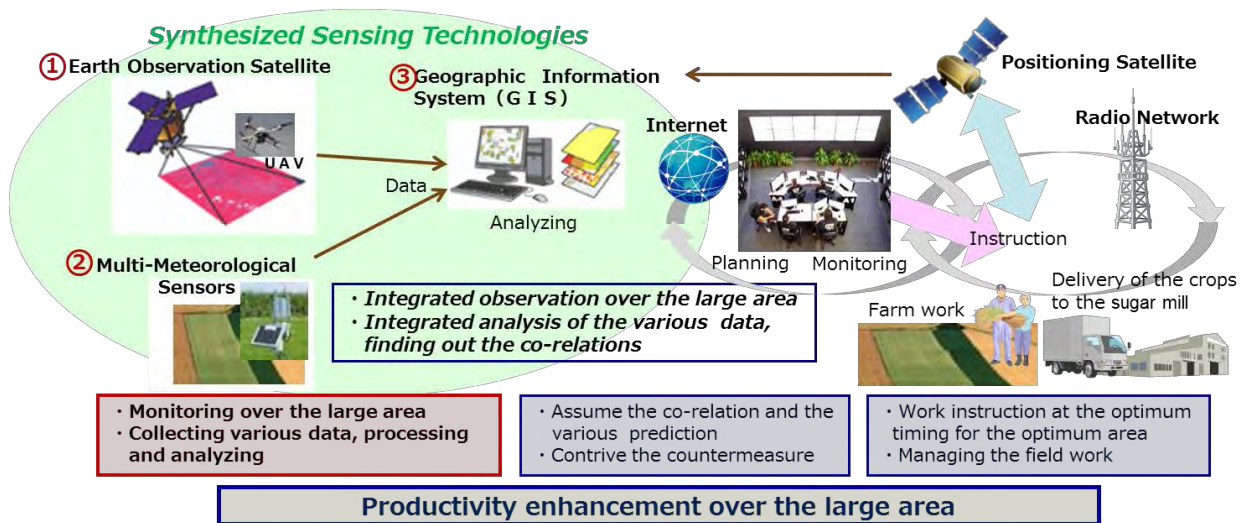

Figure 1. Concept of agricultural comprehensive support program

Table 1 shows the outline of the Synthesized Sensing Technology which shall be demonstrated in this project

· Agricultural Remote Sensing Technology

To come out the NDVI (Normalized Difference Vegetation Index) which shows the vegetation distribution condition and the plant activity.

To confirm the co-relation between the analysis outcome and the growth situation

· Agricultural Meteorological Data Analysis Technology

Installing the meteorological monitoring equipment, to collect data of temperature, humidity, solar radiation amount, rainfall amount, atmospheric pressure, wind velocity and wind direction.
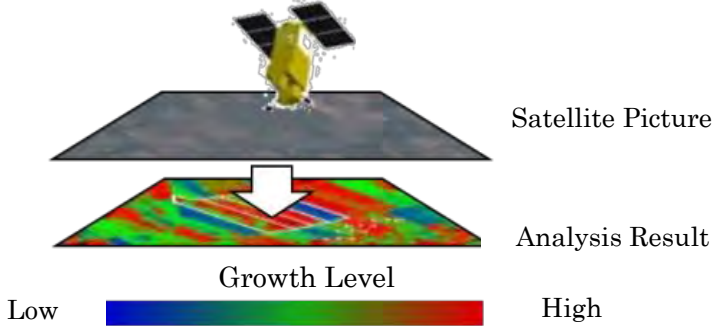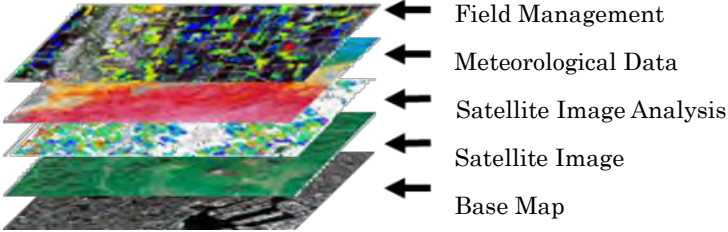
To provide the technical guidance for collecting data, operating and maintaining the equipment

To grasp the annual trend of the meteorological factors that will affect the growth

・Positioning Satellite Application Technology

To create the simple version of geographical information system which enable displaying the satellite image and field management data on the base map, as well as referring to the result of satellite image analysis and meteorological data, to create the simple version of geographical information system.

Table 1. Outline of the synthesized meteorological sensing technology

Agricultural Remote Sensing Technology	Satellite Picture Analysis Result Growth Level Low ▬ High
Agricultural Meteorological Data Analysis Technology	Meteorological Monitoring Equipment Temperature, Humidity, Solar radiation, Rainfall, Atmospheric pressure, Wind velocity, Wind direction
Positioning Satellite Application Technology	Geographical Information System (GIS) ← Field Management ← Meteorological Data ← Satellite Image Analysis ← Satellite Image ← Base Map

1.4 Implementation Work Split

　For implementing this project, our counterpart organization (PTPN-X) provide support. Table 2 shows the split of work.

・Agricultural Remote Sensing Technology

NEC analyze the field situation by using the satellite image analysis result as well as using the agricultural management info which PTPN-X provides. Both parties execute in collaboration the field investigation on the growth situation

・Agricultural Meteorological Data Analysis

NEC provide to PTPN-X the technical guidance on operation of meteorological monitoring equipment. PTPN-X collect the data by using this equipment.
NEC analyze these collected data.

・Positioning Satellite Application Technology

Based on the location info (block #, its latitude and longitude) provided by PTPN-X, NEC create the simple version of GIS and build the database for satellite image and agricultural meteorological data analysis.

Table 2. Split of work

	PTPN-X	NEC
Agricultural Remote Sensing Technology	・Provide the info of farm field and harvesting ・Monitor the growth ・Support for　NEC field survey	・Purchase satellite image, image analysis ・Field survey
Agricultural Meteorological Data Analysis Technology	・Provide the location for installation ・Build the security facility ・Operation and maintenance ・Collect meteorological data	・Purchase meteorological monitoring equipment, and its transportation ・Install and give guidance of operation ・Data analysis
Positioning Satellite Application Technology	・Provide the location info of each　block of the field	・Create simple version of GIS ・Build database of satellite image and meteorological data

Deloitte Tohmatsu Consulting LLC executed the tasks as below, assisted by the local agricultural expert of sugar agriculture:

· The research on public business environment and market research
· The research on sugarcane agriculture
· The support for field activity and coordination with the PTPN-X (by agricultural expert of sugarcane)

2. Current Situation and Issues of the Sugar Agriculture

2.1 The Current Situation of Sugar Agriculture

With regards to the sugarcane production of Indonesia, the production amount for 5 years from 2010 to 2014 decreased from 2010 to 2011, after that turned to increase from 2012 to 2013, then turned to decrease in 2014, which shows the instability of sugar production of Indonesia. With regards from 2012 to 2013, the climate was favorable for the sugar production, while in 2014, the climate was unfavorable.
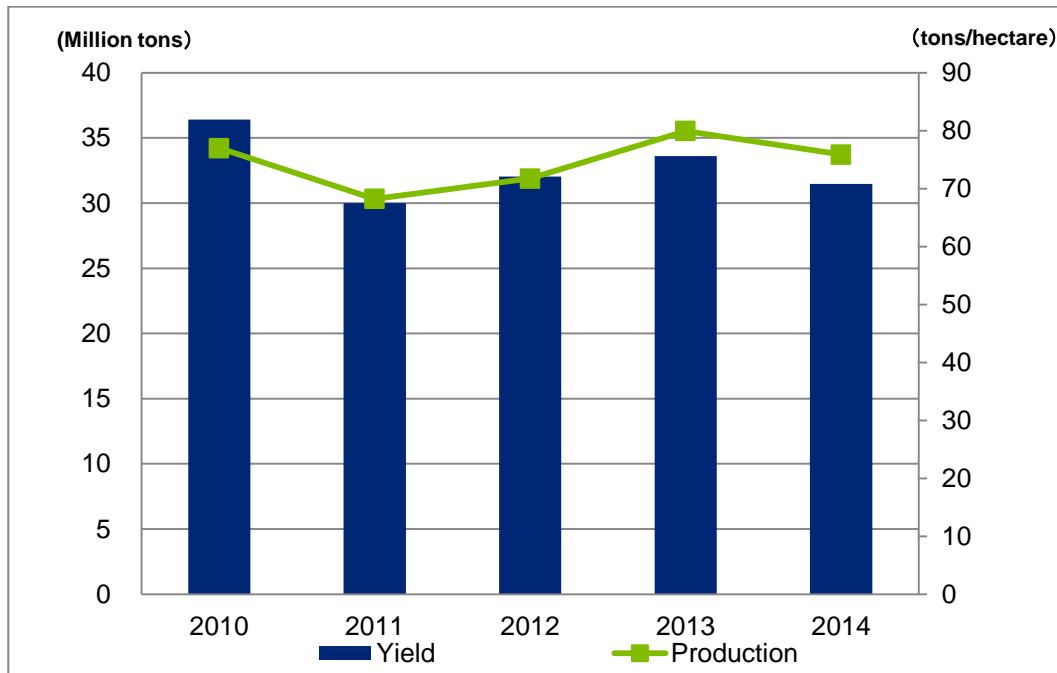

Figure 2. Sugarcane production for the past 5 years

(Source) Drawn up by Deloitte based on the data obtained in Indonesia

Furthermore, the sugar production amount in the past 5 years is less than 3 million tons, shifting between 2.2 million tons and 2.6 million tons. Meanwhile, the consumption amount of sugar is more than 5 million tons, with more than 3 million tons depending on import annually. The consumption amount of sugar will increase, so that production increase of the sugarcane and departure from the import dependency are the urgent issues.
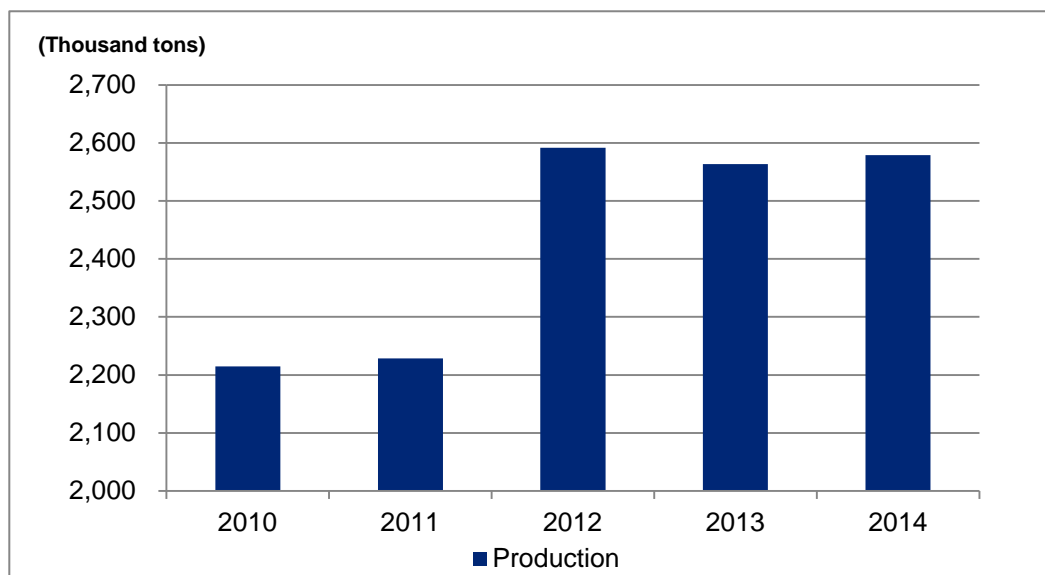

Figure 3. Sugar production for the past 5 years

(Source) Drawn up by Deloitte based on the data obtained in Indonesia

2.2 Issues

Figure 4 shows the sugarcane farm field of PTPN-X. The blue line shows the boundary of the blocks, and the sugar cultivation is controlled and managed block by block. The number of blocks is approximately 800, and the total area is approximately 3,800ha. For each block, planting of the sugarcane is executed for half a year, starting from the end of March. For cultivating the sugarcane, it takes more than a year, and the harvesting is executed for half a year, starting from May of the next year. During this term, agricultural management for the various kinds of plants and cultivation is implemented, so that complicate agricultural management over the large area is required. Figure 5 shows a sugar farm field where the sugarcane has grown to the maturity. The height of sugarcane is much higher than that of human being, so that it is difficult to recognize the situation of inner space from the ribbing. As for monitoring the meteorological factors which is crucial for growing the crops, the measurement equipments are not sufficiently available.

The synthesized sensing technology is the technology to grasp and manage in an integrated way the observed data of the large farm filed situations as well as the information of cultivation, making full use of location information. The guiding indication for improving the productivity will be obtained by creating the platform to facilitate understanding how the climate and the cultivation process affect the production volume, on whose platform accumulating and analyzing the data shall be executed.
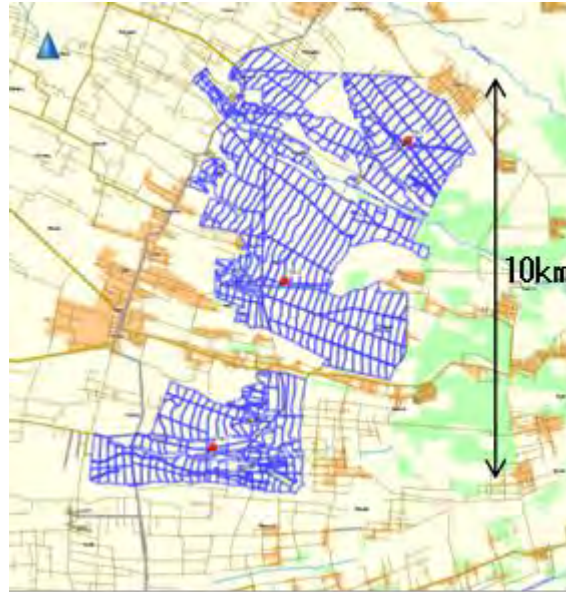
Figure 4. Map of sugarcane farm field

Figure 5. Sugar farm filed

3. Contents and Results

3.1 Agricultural Remote Sensing Technology

The remote sensing technology, which uses the earth observatory satellite, is the technology to find out the information of the kinds and conditions of the observed objects, by analyzing the wavelength band images, which are obtained by the multi spectrum sensor mounted on the satellite. In agriculture, the vegetation index and the color images are mainly used. The vegetation index is obtained by calculating the reflection rate of the red color value in the visible range and the value in the infrared range. This utilizes the characteristics of vegetation that the chlorophyll of the plant absorbs the visible light while the infrared light is strongly reflected by the cell structure of the plant. The color images are synthesized from the wavelength band of blue, green and red in the visible range.
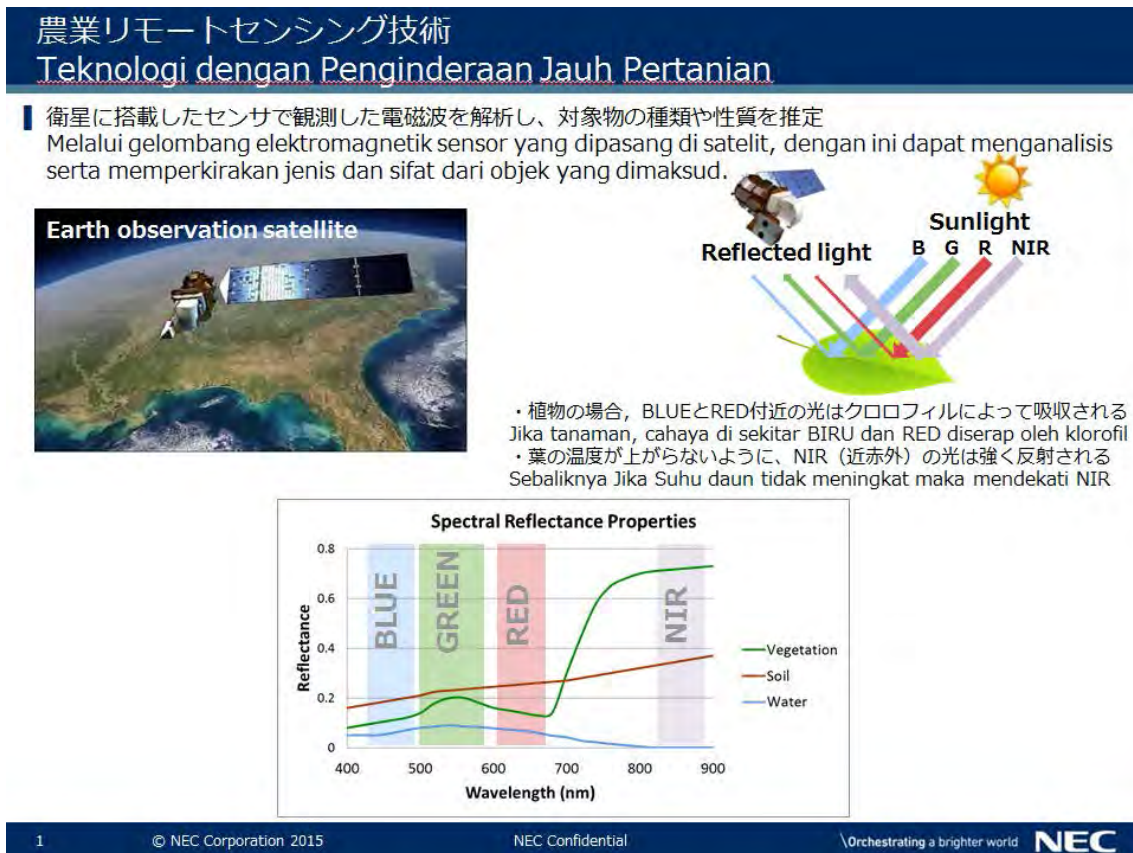

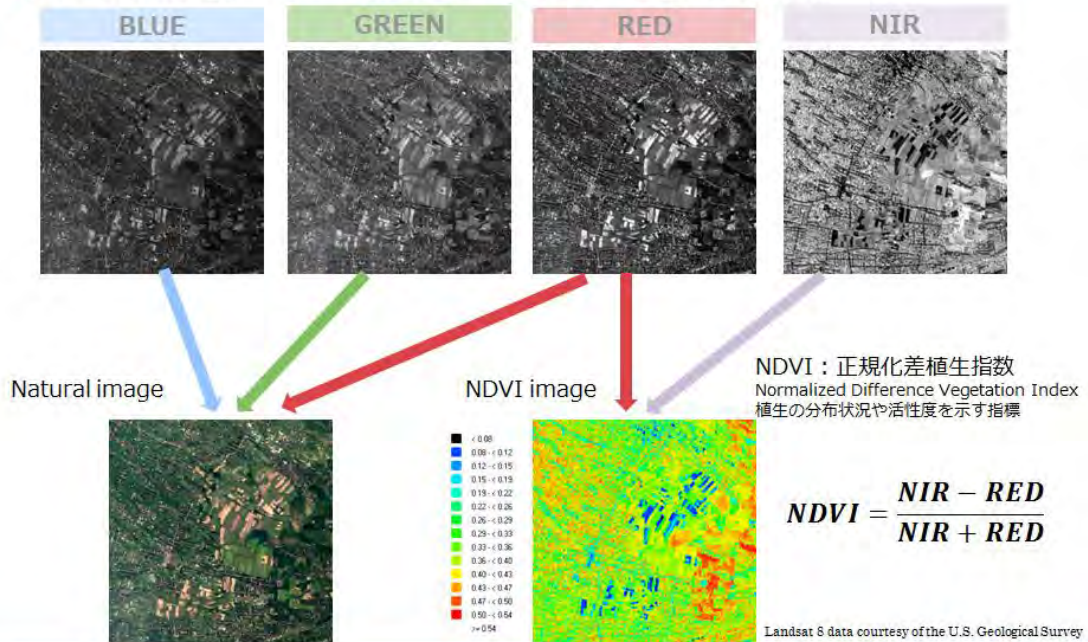**Figure 6. Agricultural remote sensing**

Figure 7. Image processing

3.1.1 Acquisition of the Appropriate Satellite Images

   In case of implementing the agricultural remote sensing by monitoring the field from the earth observatory satellite , which utilize the visible lights and infrared lights, the cloudy weather is a major   limiting condition, which is a peculiar character of the tropical areas, including the target area of this project. Therefore, we evaluated the effect of the cloudy weather in the target area, utilizing the satellite images which have been acquired in the past.

   In the dry season, many high scored (clear) images are acquired. The images with little clouds are 71%, which can be regarded as favorable.
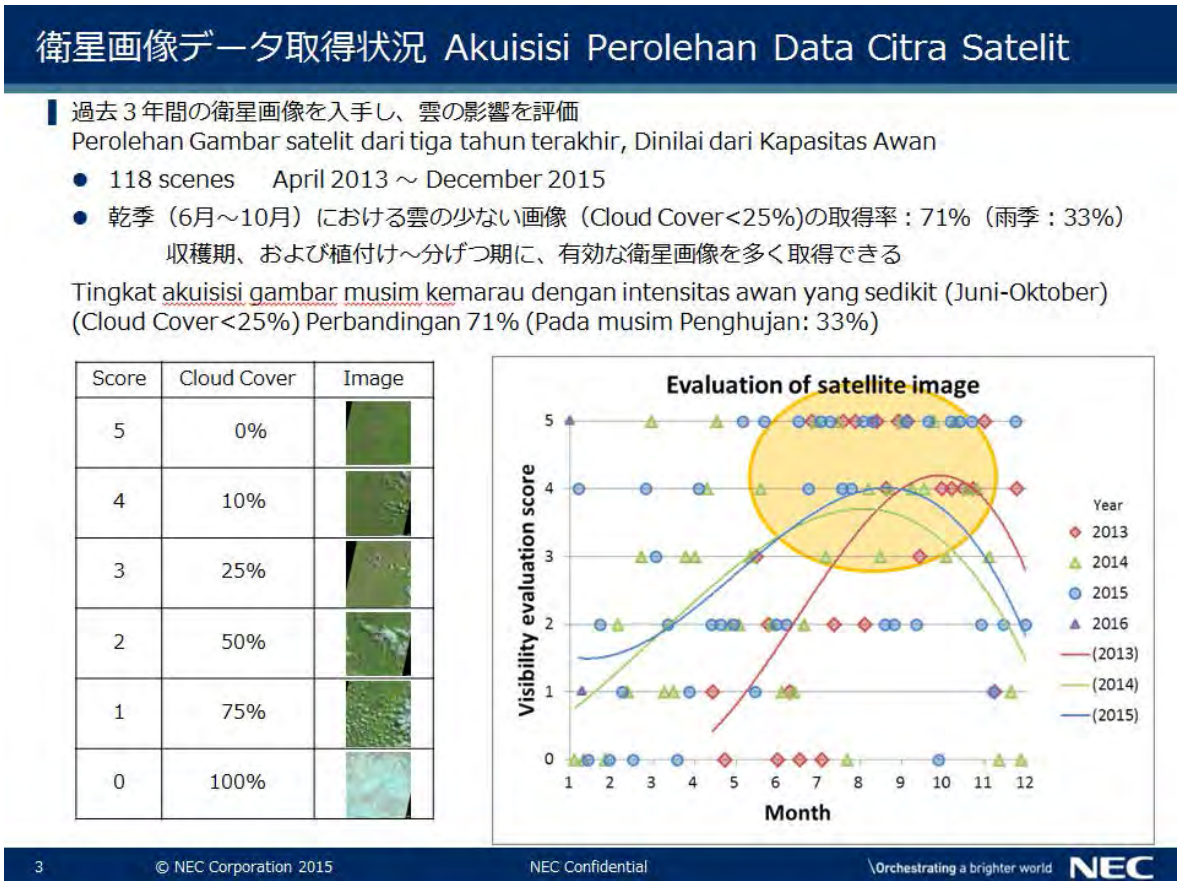

Figure 8. Acquisition of the appropriate satellite images

3.1.2 Satellite Image Analysis

Figure 9 shows an example of satellite images (for 2 months from March 2015 to January 2016)

Figure 9. Satellite image analysis

Figure 10 shows the time-series changes of NDVI from 2013 July to 2015 November and the corresponding satellite images.　It can be confirmed that the changes of cultivation situations and growth situation correspond to the variety of NDVI values.
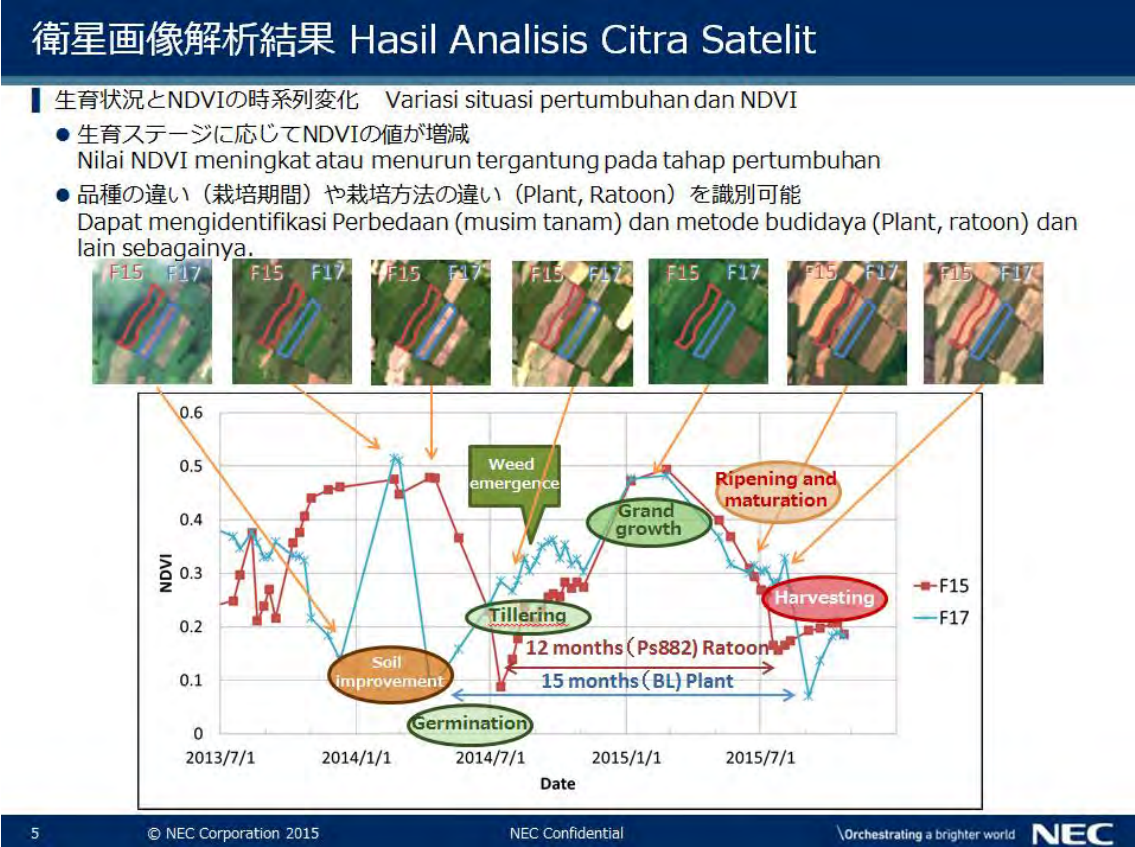

Figure 10. Results of satellite imagery analysis

3.1.3 Field Survey

We executed the field survey with the aim to confirm whether there exists co-relation between the result of satellite image analysis and the data which are collected on the ground.

In corresponding to differences of the growth situation which is come out by the satellite image analysis, the differences of the height and of the density of the sugarcanes are confirmed.
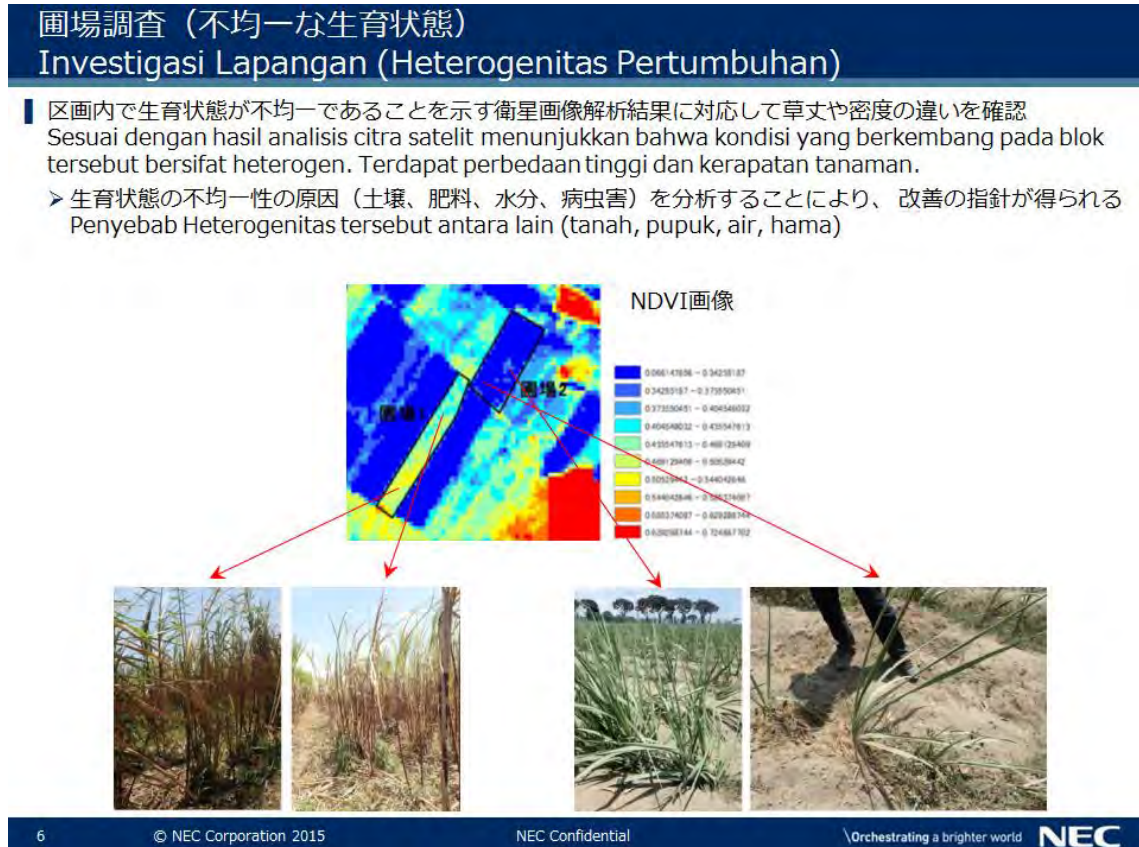

Figure 11. Field survey

As a summary of the agricultural remote sensing technology, the below items are verified:

a. Although the target area belongs to the tropical area, the effectual satellite images can be acquired as there are comparatively little clouds in the morning. Especially in the dry season, many satellite images with little clouds are acquired. Therefore, it is possible to grasp over the large field the progress of cultivation work, such as harvesting the sugarcane and planting etc., and the growth situations at the early stage.

b. With regards to the target crop (Sugarcane), the difference of vegetation index, which is calculated from the satellite images, corresponded to the difference of growth situations, which were confirmed on the ground. Therefore, agricultural remote sensing proved to be usable. Especially, in addition to the difference of the growth situations for different blocks, difference of the growth situations within the same block can be confirmed. The sugarcane grows taller than the human being, so that this technology enables grasping the various growth situations in a block, which cannot be seen from the ribbing.

By analyzing the causes of the bad growth situation (soil, fertilizing, water, pest and disease etc.), indications of improvement are expected to be obtained.

3.2 Agricultural Meteorological Data Analysis Technology

Meteorological monitoring equipment collect and accumulate the agricultural meteorological data, and execute the automatic operation by the solar electric generation. Installing this equipment in the sugarcane field, the data in Figure 12 are collected and accumulated by every 10 minutes automatically. Monitored data: temperature, humidity, solar radiation amount, rainfall amount, atmospheric pressure, wind velocity, wind direction
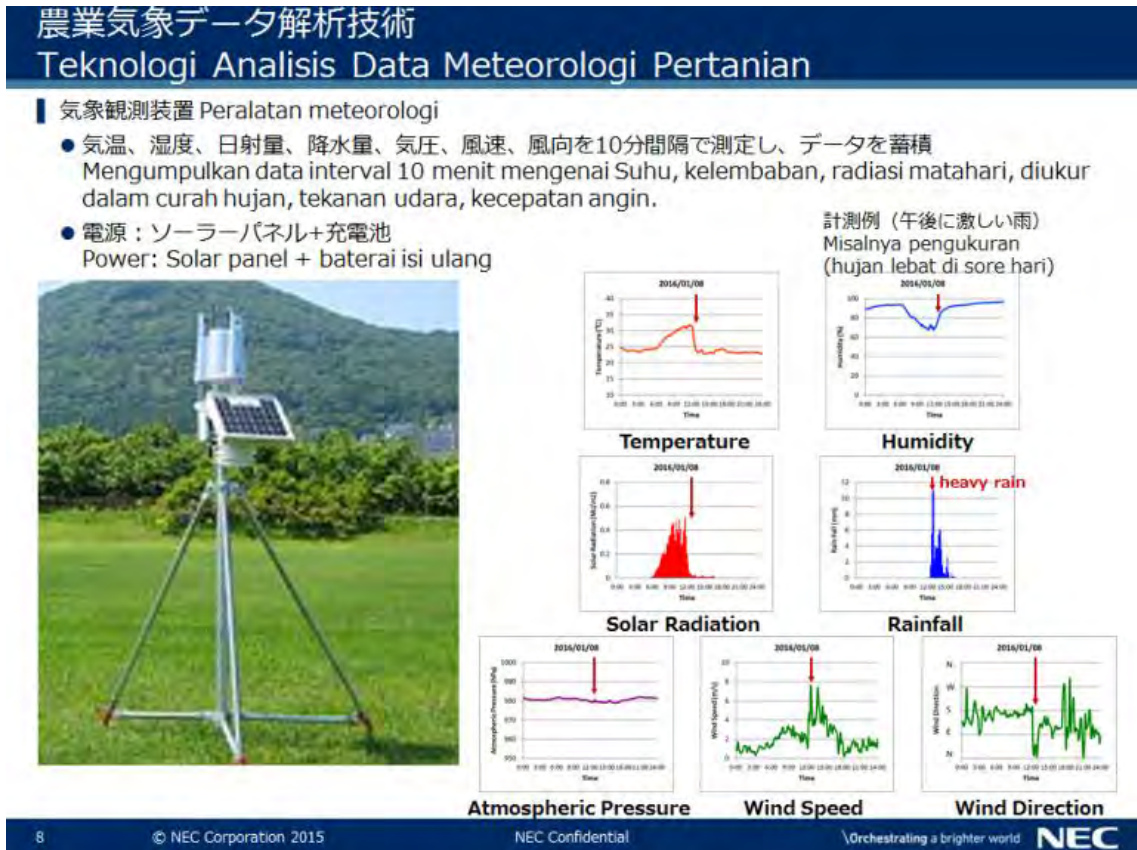

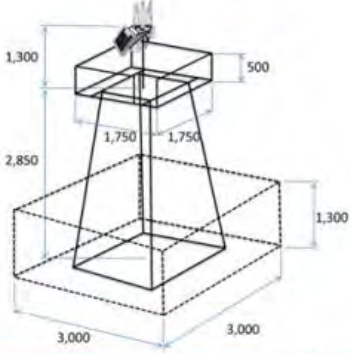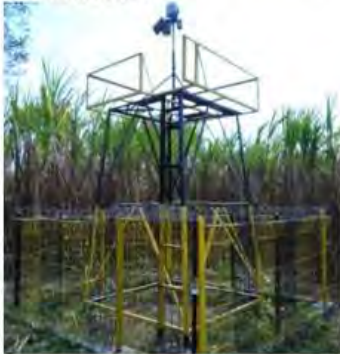**Figure 12. Agricultural meteorological data analysis**

3.2.1 Installation

Figure 13 shows the installation points. We installed the meteorological monitoring equipment in the 3 points of red pin mark (No1~No3). Distance between No.1~No.3 is 9km. By placing the meteorological monitoring equipment upon the tower, the height of the tower is about 4m, so that the equipment is able to collect the data of solar radiation and wind precisely, not hindered by the surrounding sugarcanes.

Figure 13. Meteorological monitoring equipment installation

3.2.2 Monitoring Outputs

Figure 14 and Figure 15 are the example of monitoring outputs (Temperature, Humidity, Solar Radiation, Rainfall Amount, Atmospheric Pressure, Wind Velocity and Wind Direction).
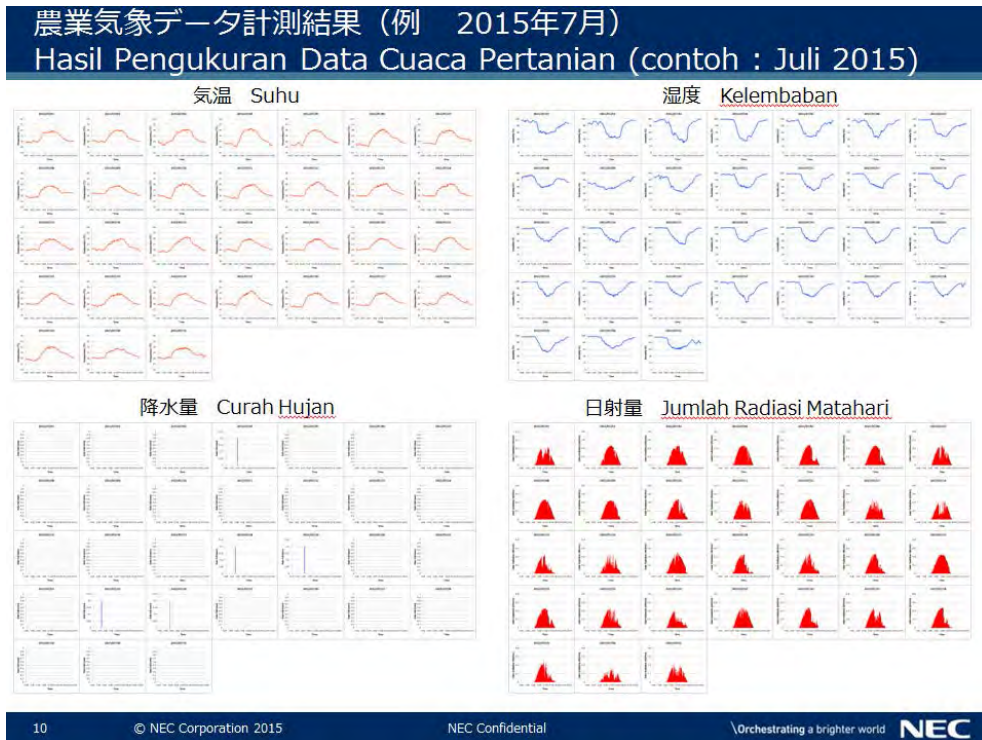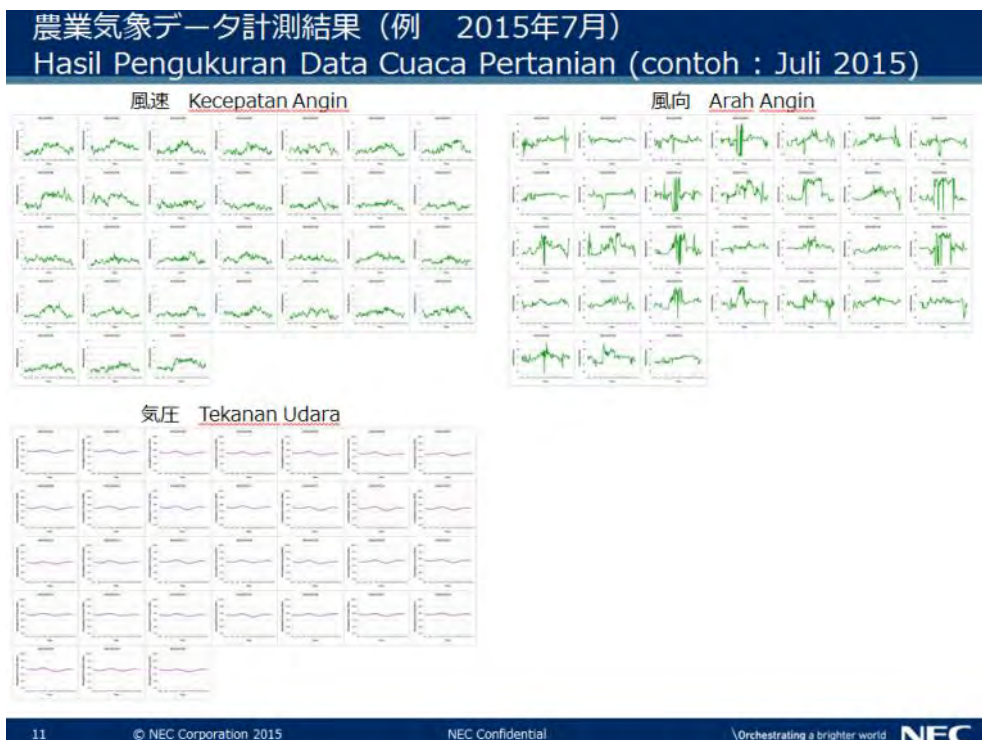

Figure 14. Example of monitoring outputs

Figure 15. Example of monitoring outputs

Figure 16 shows the meteorological trend of the rainy season and the dry season. Average temperature of rainy season is 2 degrees higher than the dry season. This is due to the fact that the lowest temperature in a day in the dry season is lower than the rainy season. That is to say, the temperature difference per a day in the dry season is 12 degrees, while 7 degrees in the rainy season. Though the average humidity in the dry season decreases due to the monsoon, it shows the high degree through the year. Rainfall amount per a month in the rainy season is more than 300mm, while it rain little in the dry season. Due to the monsoon, the wind direction tends to be North-East in the rainy season, while South-West in the dry season.

農業気象データ解析結果
Hasil Analisis Data Meteorologi Pertanian

▌雨季と乾季の気象傾向を確認
Konfirmasi kecenderungan musim hujan dan musim kemarau

	Rainy Season	Dry Season
Average Temperature	26℃	24℃
Diurnal range in Temperature (Max-Min)	7deg	12deg
Average Humidity	86%	76%
Monthly Rainfall	300mm	～0mm
Wind Direction	North East	South West

Figure 16. Meteorological trend of the rainy season and the dry season

As the result of the hearing activity regarding the relation between temperature and sugarcane cultivation, the following items are listed as the advantages of utilizing the meteorological data:
· In the ripening period of the sugarcane, the sugar content will increase in accordance with increasing of the temperature difference between the highest and the lowest in a day.
· In the grand growth period, the solar radiation amount, the solar radiating duration and the rainfall amount are important.
· At the time of applying herbicide, wind velocity and wind direction shall be taken into consideration.

3.2.3 Validity of Installment Location

Figure 17 shows the comparison of the monitoring outputs of the 3 installation points. Regarding the temperature and humidity, any outstanding difference cannot be found.

Meanwhile, the heavy rain tends to fall locally. As there is difference of rainfall amount among 3 points, the distance of each monitoring equipment can be regarded as adequate.
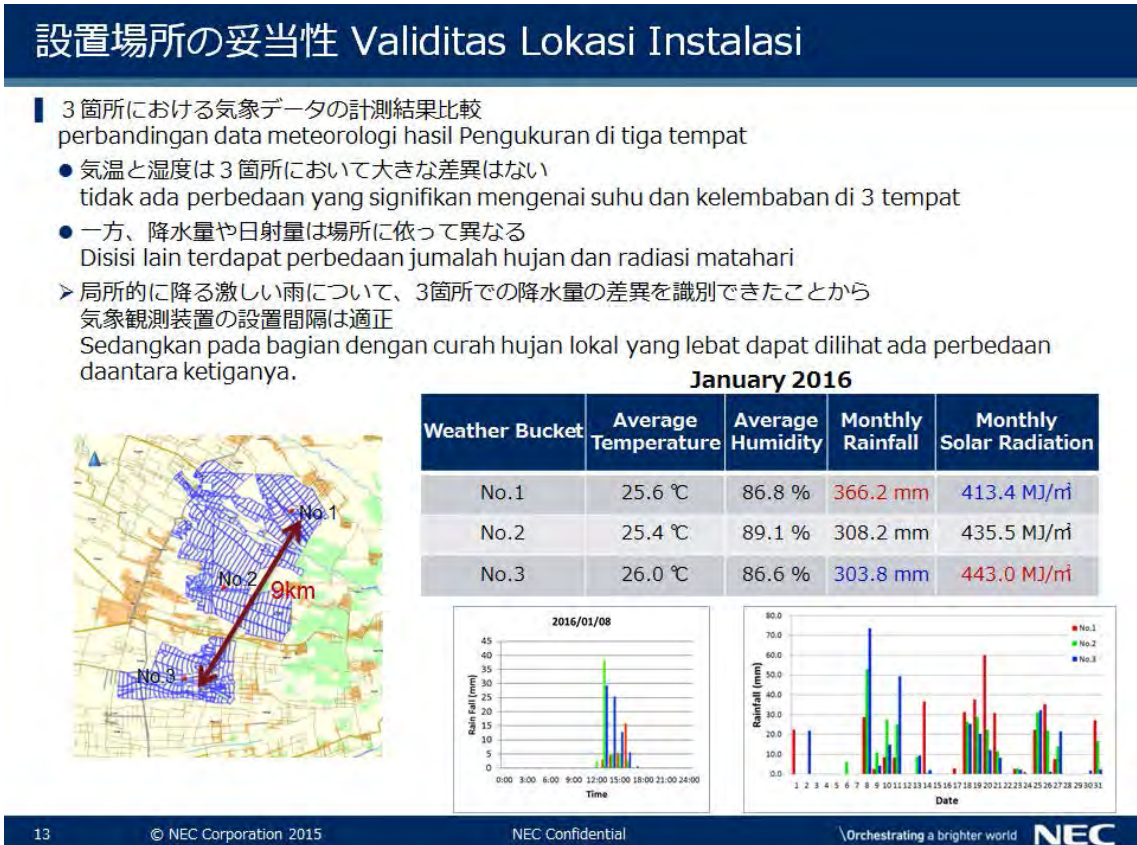

Figure 17. Validity of installment location

As a summary of the agricultural meteorological data analysis technology, the below items are verified:

a. By placing the equipment to be higher than the height of sugarcane, each meteorological data can be collected properly, without hindering the solar and wind.

b. By continuously monitoring the meteorological factors through the year, the meteorological characteristics of the rainy season and the dry season were recognized. Those meteorological data as affect the production amount and quality of the sugarcane (solar radiation amount, rainfall amount, temperature difference per a day) can be obtained.

c. Distance interval of the monitoring equipment can be regarded as adequate as they show the difference of the rainfall amount among the 3 points.

3.3 Positioning Satellite Application Technology

Our proposed Agricultural Information System is the geographical information system (GIS) which enables integrating the managements of various agricultural information on the maps, by displaying the satellite images and field management information on the base maps, as well as referring to the satellite image analysis result and the meteorological data. The below shows an example of the display screen of this system

Figure 18. Agricultural information system
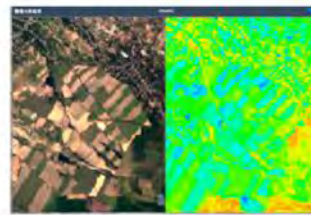
Figure 19. Agricultural information system

As a summary of the positioning satellite application technology, the below items are verified:

a. As the result of field investigation on PTPN-X sugar field, by referring to location info of GPS while moving around the field, the field map, which PTPN-X provided, was verified as accurate.

b. By utilizing this system, which enables visualization of the cultivation management, satellite images and the meteorological analysis results , those tasks like the cultivation planning, progress monitoring, harvest planning, production analysis outputting, and improvement planning can be facilitated.

c. In the sugarcane field, the communication environment (internet etc.) is not sufficient, so that building the communication infrastructure will be needed.

3.4 Local Seminar in Indonesia

We reported to the stake holders about the project contents, progress and the achievements. We executed the hearing activity to understand their request and demand.

・1st　field activity　（2015/5/10－5/22）

Project outline explanation

（PTPN-X headquarter at Surabaya）

Project outline explanation

（PTPN-X headquarter at Surabaya）

Project outline explanation　（field office at Kediri）

Project outline explanation　（Field office at Kediri）

Hearing activity toward field working department

（Field office at Kediri）

Hearing activity toward field working department

（field office at Kediri）

・2nd field activity （2015/6/14－6/19）

Explanation of how to set up the meteorological monitoring equipment

Explanation of how to set up the meteorological monitoring equipment

Progress report of satellite image analysis

GIS demonstration

・3rd field activity （2015/9/13－9/18）

Progress report of satellite image analysis and meteorological data analysis

Hearing activity about agricultural field management

· 4th Field activity （2016/2/21－2/26）

Activity achievement report

（PTPN-X headquarter at Surabaya）

Activity achievement report

（PTPN-X headquarter at Surabaya）

Activity introduction

（ Ministry of Agriculture at Jakarta）

Activity introduction

（Ministry of Agriculture at Jakarta）

· 5th Field activity （2016/4/10－4/16）

Activity introduction

（ Ministry of Agriculture at Jakarta）

Activity introduction

（ County government at Kediri）

Figure 20. Local seminar in Indonesia

Our achievement report has made PTPN-X understand on the utility of synthesized sensing technology. In the discussion with the quality control department, they expressed that not only enhancing improvement but also improving the degree of accuracy of yield prediction is their challenge to overcome, and also expressed their expectation toward utilizing high resolution satellite image and spectral sensing technology in the future. Improving the accuracy of yield prediction is important for making the optimum plan of the sugar mill operation, in terms of corporate management, and also important for stabilizing the price of sugar in the sugar market of Indonesia, in terms of national sugar import control. Therefore, we would like to positively investigate on applying this synthesized sensing technology to the yield prediction, as well as on expanding it to the contracted sugar farmers. Ministry of Agriculture (section in charge of plantation) in Indonesia showed their recognition that this technology has potentiality to contribute to improving the productivity of sugarcane of Indonesia. Ministry of Agriculture expressed their expectation for further collaboration with us because the productivity of the recent years showed the decreasing trend and is far from sufficient for the domestic demand. They advised to us that, in case of business deployment as G2G project, the deployment area should cover the East Java province and include the other enterprises, meanwhile, in case of limiting the area to Kediri, B2B business is more feasible.

3.5 Conclusion

By applying the agricultural remote sensing technology and agricultural meteorological data analysis technology, the basic platform were built, which enables monitoring the growth situations over the large area, under the conditions of various cultivations (breed variety, seeding timing, cultivation method etc.) as well as of the various meteorological factors (temperature, rainfall amount, solar radiation amount etc.). Furthermore, the positioning satellite application technology, which enables integrating the managements of information of more than 800 blocks, was verified as useful. By utilizing these platforms to execute the precise analysis, it can be expected to obtain the indication for yield increase.

4. Toward Business Development

Through this project, we have created the platform to monitor the growth situation of sugarcane and meteorological environment over the large area. As the result, we verified the utility and the demand of the synthesized sensing technology. In order to sophisticate the sugar agriculture of Indonesia as well as enrooting this synthesized technology into Indonesia, we have a tentative scenario as following.

1st STEP is to execute the demonstration of integrated solution, which facilitates giving the proper instruction to the field workers at the proper timing, as well as facilitates analyzing the outcome of harvesting/sugar milling, making the improvement plan and diagnosing its effectiveness through monitoring the progress of implementation of this improvement plan.

As the yield prediction is expected, high level of sensing technology, further data accumulation and analysis shall be implemented. Concurrently, building the communication infrastructure and ICT infrastructure (sensing system etc.) shall be implemented. The project shall be implemented as the joint pilot project of PTPN-X and NEC with the farm scale of 10,000ha. In this way, both parties build the model case of advanced ICT agriculture in Indonesia as well as execute the capacity building to create the unique intellectual property right.

2nd STEP is to expand the agri ICT technology to the whole of contracted farmers of PTPN-X (80,000ha). Currently PTPN-X is rendering the technical assistance to the contracted farmers, so that it will be efficient to utilize this scheme to expand the technology.

For these phases, we would like to propose utilizing the ODA program for the purpose of disseminating and enrooting the Japanese ICT technology into the sugar agriculture in Indonesia.

3rd and 4th STEP is the commercial phases. Consortium of PTPN-X and NEC shall provide the solutions. As for the business model, we assume the revenue share model.

Once the solutions mentioned above are created, it would be easy to expand them to the other area in Indonesia and to the other countries, as well as customize them for the other crops.

5. Expected Effects

Table 3 shows the expected effects by applying our synthesized sensing technology. Our technology is expected to improve the productivity of sugarcane agriculture of Indonesia, which in turn will improve the self- sufficiency for domestic sugar demand. In addition, this technology is applicable to the other agricultural fields and the other sectors, so that various benefits will be expected in the fields other than sugar agriculture.

Table 3. Expected effects

	Farmers	PTPN-X (and the other state-owned sugar enterprises)	Indonesia
Direct Effects	➢ Producing the high quality sugarcane leads to the high price trade in the market, which increase the income of the farmers. ➢ Enabling more stable production will decrease the price fluctuation due to the meteorological factors. ➢ Improve the traditional style of agriculture through technical transfer.	➢ Corporate revenue will increase owing to quality improvement and yield increase. ➢ Owing to visualization of growth situations by using NDVI etc., effective measures can be contrived proactively for problematic spots. ➢ Enabling the yield prediction will facilitate making the production plan. ➢ Enabling measuring the sugar content without cutting the cane will facilitate the prediction of sugar content.	➢ By deploying the technology to the other areas in Indonesia, domestic production will increase, which in turn improve the self-sufficiency in Indonesia (expedite the departure from dependency on importing sugar). ➢ Owing to decrease of the import dependency, strengthen the tolerance against the effect of price fluctuation overseas, which in turn lead to stabilizing the domestic price.
Indirect Effects		➢ Enhance the human resource capability ➢ Enable the optimum allocation of human resources in the field operation ➢ Create the new business model by utilizing the synthesized sensing technology	➢ By applying this technology to the other crucial crops, contribute to improving Indonesian agriculture as a whole. ➢ This technology is applicable not only for agriculture but also the other fields like disaster prevention. ➢ Indonesia can be the model case of cutting-edge technology agriculture in ASEAN nations.