### PROGRAMME

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<td>8:30 - 9:00</td>
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<td><em>Opening Session Chair</em> Jun Matsumoto</td>
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<td>9:00 - 9:10</td>
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<td><em>Masaru Mizoguchi (University of Tokyo, Japan)</em></td>
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<td><em>Florentina S. Dumlao, President, Nueva Vizcaya State University (Philippines)</em></td>
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**Session 1: Climatic changes in Asian monsoon region (1)**  
**Chair:** Tsuneo Kuwagata

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| 9:20 - 9:40  | *Jun Matsumoto (JAMSTEC/TMU, Japan), Marcelino Villafuerte II, Hiroshi Takahashi,*  
              | *Ikumi Akasaka and Hisayuki Kubota:* Long-term trends and variability of rainfall extremes  
              | in the Philippines                                                                      |
| 9:40 - 10:00 | *Ikumi Akasaka (TMU, Japan), Hisayuki Kubota, Marcelino Villafuerte II, Esperanza O.  
              | *Cayanan and Jun Matsumoto:* Seasonal march of rainfall and its year-to-year variations in  
              | the Philippines                                                                       |
| 10:00 - 10:20| *Jianqing Xu (JAMSTEC, Japan), Jun Matsumoto, Hisayuki Kubota, Ikumi Akasaka,*  
              | *Miki Hattori, Tomoshige Inoue and Esperanza O. Cayanan:* Onset signal of the summer  
              | monsoon observed from the surface downward longwave radiation in Laoag of Philippines |
| 10:20 - 10:40| *Tomoshige Inoue (JAMSTEC, Japan), Jun Matsumoto and Nobuhiko Endo:* Changes in  
              | boreal autumn rainfall in the recent 50 years (1961-2010) over the Indochina Peninsula |
| 10:40 - 11:00| Coffee break                                                                                 |

**Session 2: Climatic changes in Asian monsoon region (2)**  
**Chair:** Ikumi Akasaka

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| 13:50 - 14:10| *Masaru Mizoguchi (UT, Japan):* Fundamentals of Field Monitoring System (FMS) in Asian  
              | monsoon region                                                                              |
| 14:10 - 14:30| *Patricia Mae C. Bonife and Gemma T. Narisma (Ateneo de Manila University,  
              | Philippines): Investigating potential relationship between climate change impacts and rice  
              | production in the Philippines                                                                |
| 14:30 - 14:50| *Felino P. Lansigan (UPLB, Philippines) and Francis John F. Faderogao:* Assessing climate  
              | change impacts on crop productivity in selected rice-growing areas in the Philippines      |
| 14:50 - 15:10| *Wilfredo A. Dumale Jr. (Nueva Vizcaya State University, Philippines) and Masaru  
              | Mizoguchi:* Potential applications of the field monitoring system (FMS) for local and farmer-  
              | level climate change adaptation in agriculture                                               |
| 15:10 – 15:30| *Chusnul Arif (UT, Japan), Masaru Mizoguchi, Budi Indra Setiawan and Ryoichi Doi:*  
              | Optimizing water management of system of rice intensification for climate change adaptation  
              | strategy based on field monitored data                                                       |
| 15:30 - 15:50| Coffee break                                                                                 |

**Session 4: Climatic change effect on agriculture in Asian monsoon region (2)**  
**Chair:** Kei Tanaka

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| 15:50 - 16:10| *Virgillo Julius P. Manzano Jr. (Mariano Marcos State University, Philippines) and  
              | *Masaru Mizoguchi:* Soil moisture monitoring using field monitoring system (FMS)  
              | and analysis of rainfall data for tomato cropping calendar under Batac City, Ilocos Norte,  
              | Philippines Condition                                                                      |
| 16:10 - 16:30| *Florentina S. Dumlao (Nueva Vizcaya State University, Philippines) and Reginald Laxum  
              | T. Atabay:* Vulnerability analysis and climate change mitigation strategies of the Aringay  
              | River Watershed, La Union, Philippines                                                     |
| 16:30 - 16:50| *Bernardo S. Umapuang (Nueva Vizcaya State University, Philippines):* Recycling of  
              | abattoir wastes (cattle rumen contents) for animal feeding: A localized alternative to climate  
              | change mitigation                                                                           |
| 16:50 - 17:10| *Mild T. Rumusod (Nueva Vizcaya State University, Philippines):* Agbibinnulig: An Iloko  
<pre><code>          | cultural resource in managing water problems in rice farming                               |
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<td>17:10 – 17:30</td>
<td>Agustin Lunag (Nueva Vizcaya State University, Philippines) and Merlinda P. Calubaquib: Installation of Participatory Guarantee System (PGS) for Organic Farming Practitioners in Nueva Vizcaya</td>
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<td>17:30 – 17:50</td>
<td>Atsuko Tanaka, Seishi Ninomiya, Yumi Mori, Toshiya Takasaki, Yasukazu Okano, Takaharu Kameoka, Takashi Togami, Kyosuke Yamamoto, Akanae Takezaki, Ryoichi Ikeda, Toru Ishida, Masaru Mizoguchi (UT, Japan): Youth mediated communication model: site-specific decision support system under climatic change</td>
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<td>17:50 – 18:40</td>
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**March 5, 2013**

**Session 5 Climatic change effect on agriculture in Asian monsoon region (3)**

**Chair: Masaru Mizoguchi**

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<tr>
<td>9:00 - 9:20</td>
<td>Dhanachandran Sudharsan (UT, Japan) : Development of decision support system for suitable crop simulation in Northeast Thailand</td>
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<td>9:20 - 9:40</td>
<td>Mallika Srisutham (UT, Japan) , Masaru Mizoguchi and Ryoichi Doi: Cassava growth after rice in sandy soil with no-irrigation in Northeast Thailand</td>
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<td>9:40 – 10:00</td>
<td>Somsak Sukchan (Land Decvelopment Department, Thailand) TBD</td>
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<tr>
<td>10:00-10:20</td>
<td>Kei Tanaka (NARO, Japan), Takuji Kiura and Hiroe Yoshida: Prediction system to optimize double cropping of rice and cassava in Thailand</td>
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<td>10:20-10:40</td>
<td>Coffee break</td>
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**March 6, 2014**

Field Trip
Good morning ladies and gentleman,

It is my great pleasure and honor to deliver the welcome address in the second international workshop of “Climatic changes and their effects on Agriculture in Asia Monsoon region”. I would like to express my sincere gratitude to President Florentina Dumlao, Prof. Wilfredo Dumale and the staffs of Nueva Viscaya State University who are hosting us at Baguio for this workshop. I would also like to express sincere appreciation to all the participants from Indonesia, Thailand, Vietnam, Japan and Philippines in spite of your busy schedule.

As you know, the earth is unstable recently. There are a lot of disasters such as earthquakes, flood, droughts, etc. all over the world. Climate change is one of biggest issues in global scale. On the other hand, a lot of people are living in our Asia monsoon area. It is the important issue for us to keep food against climatic change. In this background, we have started this project, “Climatic changes and their effects on Agriculture in Asia Monsoon region” under the research framework of the Green Network of Excellence (GRENE) for five years, the Japanese fiscal years from 2011 to 2015 supported by the Japanese Ministry of Education. This project aims to improve the reliability of future climate prediction and to develop the information platform which will be useful to design adaptation and mitigation strategies in agriculture against the predicted climatic changes in Asian monsoon region.

The budget of this project was reduced this year because some were used for the reconstruction from the big earthquake. However, fortunately the budget of this project is recovered and increased a little from next month. I have just submitted the budget plan to Monbu-kagakusho last Thursday. This is good news in order to promote our project.

Anyway, the major objective of this workshop is to discuss our research progress after the first workshop in Bangkok and promote our collaboration. I believe this workshop is an excellent opportunity for all of us to exchange our ideas and professional experiences and will inspire the sense of solidarity among participants.

I wish sincerely the success of the workshop.

Thank you very much. (salamat sa inyo)
Long-term Trends and Variability of Rainfall Extremes in the Philippines

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Keywords: rainfall extremes, rainfall intensity, precipitation indices, long-term trend, Philippines

1. Introduction

In the Philippines, Jesuits founded the meteorological observatory at Manila in 1865 and observation network was established in the whole country until the end of the 19th century, then the observational system was developed further under the USA colony until the World War II [1]. The results of these observations were listed in the publications, such as “Monthly Bulletins of Philippines Weather Bureau” for the period 1900-1940. We digitized the daily rainfall data at approximately 40 stations of which the locations are close to present Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA) stations. The data of PAGASA are available since 1950. Since rainfall in the Philippines is highly seasonal due to the monsoons influencing it [2] and the country’s rainfall also showed sensitive response to the El Niño Southern Oscillation (ENSO) during July-September (JAS, peak of the southwest monsoon) and October-December (OND, early stage of the northeast monsoon) [3], this study examines the variability and trends in rainfall extremes in the country during JAS and OND.

2. Data

We use daily rainfall data from 35 meteorological observing stations of PAGASA (Fig. 1). The stations have near-complete data during the common period of 1951-2010. To examine the rainfall extremes, at least five of several precipitation indices developed and recommended by the Expert Team on Climate Change Detection and Indices (ETCCDI, http://ccema.seos.uvic.ca/ETCCDI/list_27_indices.shtml) and two additional wet and dry spell indices, which are applicable for monsoon regions [5], are used. Table 1 describes the indices used in this study. Additionally, the recently digitized rainfall data during the pre-1940s (can be accessed through: http://www.jamstec.go.jp/drc/maps/e/), is used to understand the precipitation indices in a longer time-scale. The non-parametric Mann-Kendall trend test is used to detect significant trends among these indices.

3. Results

Significant increasing trend (above 90% confidence level) is found in Rx5D at seven stations located in the northwest and central Philippines during JAS (Fig. 2a). During OND, there are two stations, located in the east and west coasts of the country, which are significantly decreasing (95% confidence level) and two neighboring stations on the northwest with significant increasing trend at the 90% confidence level (Fig. 2b). On the other hand, DSDx has three (two) stations with significant decreasing (increasing) trend at the 95% (90%) confidence level during JAS (Fig. 2c). During OND, four (two) stations have significant increasing (decreasing) trend (Fig. 2d). Most of the stations with significant trends for DSDx are located in the central and southern Philippines. Aside from the Rx5D and DSDx, there are just two to six out of 35 stations with significant trends for the remaining extreme

Fig. 1. Topographical map of the Philippines with the 35 meteorological stations considered in this study; earlier rainfall data (before the 1940s) of the stations marked with star are used for Figure 3.
Table 1. Extreme rainfall indices and their definitions, each index is computed during July to September (JAS) and October to December (OND) seasons; the base period used is 1961-1990. Wet days refer to days with daily rainfall ≥1 mm.

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<tr>
<th>Index (code)</th>
<th>Definitions</th>
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<tr>
<td>p95</td>
<td>95th percentile of wet days</td>
<td>mm/day</td>
</tr>
<tr>
<td>Rx1D</td>
<td>1-day maximum rainfall</td>
<td>mm/day</td>
</tr>
<tr>
<td>Rx5D</td>
<td>maximum consecutive 5-day total rainfall</td>
<td>mm</td>
</tr>
<tr>
<td>ptot</td>
<td>seasonal wet days’ total rainfall</td>
<td>mm</td>
</tr>
<tr>
<td>p95D</td>
<td>count of days exceeding the base period’s p95</td>
<td>day</td>
</tr>
<tr>
<td>WSDx</td>
<td>longest wet spell duration*</td>
<td>day</td>
</tr>
<tr>
<td>DSDx</td>
<td>longest dry spell duration**</td>
<td>day</td>
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* wet spell refers to consecutive days with rainfall ≥ base period’s mean daily rainfall
** dry spell refers to consecutive days with rainfall < base period’s mean daily rainfall

Fig. 2. Trends in (a) Rx5D during JAS, (b) Rx5D during OND, (c) DSDx during JAS and (d) DSDx during OND; blue (red) triangles (inverted triangles) denote increasing (decreasing) trend, small (big) filled triangles are statistically significant at 90% (95%) confidence level, while open circles are not significant in either of the set levels.
rainfall indices. Found trends in the remaining indices also showed spatial incoherency.

High inter-annual variability can be observed in the time series of indices at Iloilo and Daet (Fig. 3a and 3b, respectively), which have both longer rainfall records (note that, Daet’s record begins only in 1920 because of the strict data quality that we’ve imposed; while the 10-year missing data was caused by the Second World War). Aside from the year-by-year variability, decadal fluctuation is also well pronounced in the indices at these stations. Notice the high values of the wet indices during the 1930s, which is comparable in the ’90s (’80s) at Iloilo (Daet).

4. Conclusion

Trend analyses show that the country’s precipitation tends toward wetter (drier) condition as indicated by significant increasing (decreasing) trend in the maximum consecutive 5-day rainfall totals and significant decreasing (increasing) trend in the longest dry spell duration during JAS (OND), which suggests a recent stronger (weaker) southwest (northeast) monsoon. These trends can also be partly attributed to a high inter-decadal variability in the indices of extreme precipitation as suggested by the stations with earlier pre-1940s rainfall data. However, it is important to note that spatial incoherency exists in the observed trends; thus, factors affecting precipitation extremes may differ from station to station in the country. The results obtained here stress the need to identify factors governing extreme precipitation indices on specific locations in the Philippines.

Acknowledgement

This study was supported by the “Green Network of Excellence (GRENE)” program by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan. This research was also supported in part by Grant-in-Aid for Scientific Research of the MEXT 20240075 and the Global Environmental Research Fund (B-061 and A-0902) of the Ministry of the Environment, Japan. M. Villafuerte is a recipient of Asian Human Resources Fund scholarship provided by the Tokyo Metropolitan Government.

References

Seasonal March of Rainfall and its Year-to-Year Variations in the Philippines

Ikumi Akasaka1*, Hisayuki Kubota2, Marcelino Villafuerte II1,3, Esperanza O. Cayanan3 and Jun Matsumoto1,2
1Tokyo Metropolitan University, 1-1 Minami-Osawa, Hachioji 192-0397 Japan, 2Japan Agency for Marine-Earth Science and Technology (JAMSTEC), 3Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA)
*akasaka@tmu.ac.jp

Keywords: Rainfall, Seasonal Progression Pattern, Year-to-Year Variation, Philippines

1. Introduction

The climate of the Philippines is warm and wet because the sea surface temperature (SST) of the surrounding ocean is warm throughout the year. The seasonality of rainfall is more extreme than that of temperature and is characterized mainly by the Asian monsoon, tropical cyclones, and topographic effects [1, 2]. Year-to-year variations and long-term changes in the seasonal march of rainfall greatly influence Philippine agriculture and economics because the seasonal march of rainfall are closely connected to planting decisions and harvesting. Therefore, whether the seasonal march of rainfall patterns will change with future global warming is of great concern to Philippine agriculture and the Philippine economy. To answer this question with a prognostic analysis, as the first step, we will clarify characteristics on the past year-to-year variations in the seasonal march of rainfall in this study.

2. Data and Methodology

Daily rainfall data from 1952 to 2008 were provided by the Philippine Atmospheric Geophysical and Astronomical Services Administration (PAGASA). We used daily rainfall data at 35 stations, the records of which included more than 80% of the data for the period 1952–2008. To smooth day-to-day variations in rainfall, pentad rainfall data were calculated only when daily rainfall data were missing during less than 20% of one pentad. First, to detect spatial and temporal patterns of rainfall, we applied empirical orthogonal function (EOF) analysis to the pentad rainfall anomalies, normalized by a cube root transformation, of 35 stations for 1952–2008. In order to classify year-to-year variations in seasonal march of rainfall patterns, we applied Cluster analysis (Euclidean distance and Ward’s method) to time coefficients obtained from the EOF analysis.

3. Results

1) Temporal and Spatial Characteristics on the Seasonal March of Rainfall

The result of the EOF analysis for pentad rainfall during 1952–2008 showed two dominant EOF modes. The first and second EOF modes account for 34.2 % and 17.8 % of the total variance, respectively. Spatial pattern of the first EOF mode (EOF1) shows a positive sign throughout the Philippines, with especially high loadings in the west coastal region at around 9–14°N (Fig. 1a). Mean time coefficient of the EOF1 changes sign during mid-May and mid-December (Fig. 1b). These results indicate that the summer rainy season starts simultaneously throughout the Philippines around mid-May and withdraws toward mid-December. That is, EOF1 shows the seasonal progression patterns in the summer rainy season. These characteristics appear remarkably in the west coastal region, where the rainy season is in the summer. In contrast, the factor loadings of EOF1 are relatively low-level in the east coastal region compared to those in the west coastal region because the amount of rainfall in the east coastal region increases from September to December rather than during the summer. The characteristics on the seasonal march of rainfall in the east coastal region are shown in results of the second EOF mode (Figure not shown).

2) Classification of the Seasonal March of Rainfall Patterns

Fig.2 shows the dendrogram of Cluster analysis. The distances between merged groups appear to increase remarkably at the stop point shown in Fig. 3. This point indicates that the analysis should stop before the point. Therefore, we determined to classify the seasonal progression patterns in the summer rainy season into six clusters (Fig.2). Mean time coefficients in six clusters are shown in Fig.4. Cluster 1 (C1) shows a change similar to the mean seasonal march of rainfall shown in EOF1 except that the peak appears around mid-October. Cluster 2 (C2) shows delayed onset and delayed withdrawal of the summer rainy season. Cluster 3 (C3) does not have distinct dry season from January to April compared with the other cluster. Cluster 4 (C4) shows earlier onset of the summer rainy season than the other clusters. Cluster 5 (C5) indicates a pattern which the summer rainy season withdraws earlier than any other clusters. Therefore, C5 has shorter duration of the summer rainy season. Cluster 6 (C6) shows distinct dry season from January to April.
Fig. 1. (a) Spatial patterns and (b) time coefficients of EOF1. Circle indicates observation stations in (a). Gray line in (b) indicates time coefficients in each year. Black line in (b) indicates mean time coefficients averaged for 1952–2008.

Fig. 2. Dendrogram of Cluster analysis.

Fig. 3. Time-evolution of the unifying process in Cluster Analysis.

Fig. 4. Classification of the seasonal progression pattern in the summer rainy season. Dotted line indicates mean time coefficients of EOF1 shown in Fig.1b.
3) Year-to-Year Variations and Long-Term Changes in the Seasonal March of Rainfall

Fig.5 shows year-to-year variations in the seasonal progression patterns of the summer rainy season. C4 and C5 appear before the late 1970s. It means that the early onset or early withdrawal of the summer rainy season tend to occur before the late 1970s. On the other hand, it was found that C2 and C3 frequently appeared since the early 1990s and the late 1990s, respectively. This means that delayed onset or delayed withdrawal of the summer rainy season frequently occurred since the 1990s. It also seems that C1 replaced C2 and C3 since the 1990s because C1 has not appeared after 1988 except for 2007. Additionally, C3 shows a peculiar pattern which does not have distinct dry season. Five of the six years classified as C3 correspond to years when the recent La Niña event was occurring around the dry season.

4. Conclusions

In this study, we classified the seasonal progression patterns in the summer rainy season for 1952–2008 into six groups. It was found that the delayed onset or delayed withdrawal of the summer rainy season frequently appeared since the 1990s. Additionally, it is noteworthy that several La Niña years, especially since the late 1990s, did not have distinct dry season. We will investigate relationship between the recent La Niña events and rainfall events during the dry season in near future. It also needs to study why C2 and C3 were remarkably shown since the 1990s by analyzing the long-term changes in the air-sea interaction in the tropics.

Acknowledgement

This research was supported by Green Network of Excellence (GREEN) and Data Integration and Analysis System (DIAS) of Ministry of Education, Culture, Sports, Science and Technology. This research was also supported in part by Grant-in-Aid for Scientific Research of the MEXT 20240075 (Leader: Prof. Jun Matsumoto) and the Global Environmental Research Fund (B-061 and A-0902) of the Ministry of the Environment, Japan.

References


Onset Signal of the Summer Monsoon Observed from the Surface Downward Long-Wave Radiation in Laoag of Philippines

Jianqing Xu1*, Jun Matsumoto1,2, Hisayuki Kubota1, Ikumi Akasaka2, Hattori Miki1, Tomoshige Inoue1, and Esperanza O. Cayanan3
1 Research Institute for Global Change, Japan Agency for Marine-Earth Science and Technology, Kanagawa, 236-0001, Japan, 2 Tokyo Metropolitan University, Tokyo, 192-0397, Japan, 3 Philippine Atmospheric, Geophysical and Astronomical Services Administration, Manila, Philippines
*jxu@jamstec.go.jp

Summary: Over 60% population is living in the Asian Monsoon region, and it is very important to know the variations of Asian Monsoon under the global climatic change. An observational project over Laoag in north of Republic of the Philippines have been conducted since 17 February 2012. The downward solar radiation and downward long-wave radiation data, which are the two elements of energy flux from the solar and the atmosphere respectively, have been observed at the surface. It is found that the long-wave radiation acts as an onset signal of summer monsoon while the solar radiation still in dry season. From the viewpoint of heat balance, the long-wave radiation increased about 17 Wm-2 within several hours, but the solar radiation flux decreased 83 Wm-2 in the following few day due to the cloudy weather. Those facts mean that the incoming radiation flux (sum of long-wave and the solar radiation flux) decreased 66 Wm-2 from the dry season to rainy season. Such a quantitative value of radiation flux could not be detected or alternated by other routine weather observation up to now. The observation of the long-wave radiation can detected the onset signal of the summer monsoon in Laoag of Philippines. The daily map of atmospheric field also supported this consequence.

Keywords: Long-Wave Radiation, Solar Radiation, Summer Monsoon

1. Introduction

Solar radiation and long-wave radiation (Fig. 1) arriving on the earth’s surface plays a key role in energy balance of the Earth-Atmosphere system. Expecting the reflected solar radiation and upward long-wave radiation, the energy acts at the ground, such as vaporizing the surface water, heating the air near the surface layer and warming the ground surface, and then surface air temperature has been decided during this process. Global warming has been noticed in recent years, but the behaviour of the resource energy that resulting the temperature rising is not clear. Although meteorological data have become much more plentiful and accessible in recent years, daily data of solar radiation and long-wave radiation at the surface over wide areas are still lacking. On the other hand, a good knowledge of daily solar radiation is essential for many applications, such as agricultural, ecological, hydrological and soil-vegetation-atmosphere transfer models.

Recently, [2] has estimated the daily solar radiation from solar duration data at more than 190 stations in China. The influences from the topography or the surroundings to the observed sunshine duration data have been considered and the raw data has been revised, the solar radiation flux dataset based on the surface observation for more than 50 years has been prepared. Adding the temperature and humidity dataset, the long-wave radiation can be obtained too.

Many countries in Asian Monsoon regions, such as Philippines, Thailand, Vietnam, and etc., have a long term of sunshine duration data. In order to expanding the coverage of the dataset including the radiation flux data, a project named Climatic Changes and Evaluation of Their Effects on Agriculture in Asian Monsoon Region of Green Network of Excellence has been started. One of the aims of this project is to development the agro-meteorological and climatological data-bases in the developing countries in Asian monsoon region. Completing an energy and water balance data set covering the Asian Monsoon region, and providing the information to the climatic (ex, checking the output of GCMs) and agricultural research (photosynthesis process).

According to [3], monsoon onset based on a local agronomic definition. The onset definition used operationally by PAGASA is the beginning of the first five-day period (in April, May, June or July) with total rainfall of 25 mm or more, including three days of at least 1 mm day-1; these conditions are required by PAGASA to be met at five or more of nine selected western stations, and Laoag is one of those stations. This definition is at the discretion of PAGASA to include elements such as rainfall amounts, clustering of rainy days, area covered and wind system (prevailing winds over the western Philippines should have westerly components from the surface up to 850 hPa level).

2. Field observations

The City of Laoag (Fig. 2) is located in the province of Ilocos Norte, Philippines. Laoag experiences the prevailing monsoon climate of Northern Luzon, characterized by a dry season from November to April and a wet season from May to October, occasionally visited by powerful typhoons. With the collaboration of PAGASA (The Philippine Atmospheric, Geophysical and Astronomical Services Administration),
we installed one set of Pyronometer (CMP/21/C, Kipp & Zonen) and Pyrgeometer (CGR 4, Kipp & Zonen) at the Laoag weather station (81.81° E, 20.52° N; weather station ID: 98233) where near the Laoag Airport.

3. Results and Discussions

Seasonal variations of the surface downward long-wave radiation in daily mean have been shown in Fig. 3. There was “jump” in May, and a “falling down” in October, and rain season was between them. From Fig.4, it is can be found that the long-wave radiation began to increase on May 13, but the solar radiation still shown clear sky condition without the decreasing due to cloudy at this time. One May 15, the sky began to be cloudy, and these was a weak rainfall has been observed in the evening of May 14.

Surface downward solar radiation (Fig.5) shows that the energy decreased during the rainfall season, the minimum value of solar radiation happed around June, July, and August. Summer solstice is in June, and the clouds coved the sky, avoid the strong sunshine reached to the earth surface.

Fig. 6 shows the seasonal variation of the total energy balance. The most minimum value of $Sd+Ld$ (sum of solar
and long-wave radiation) was in the summer monsoon season, although the top of the solar radiation was almost at its maximum at this period.

4. Conclusions

Long-wave radiation acts as an onset signal of summer monsoon
The long-wave radiation acts as an onset signal of summer monsoon while the solar radiation, precipitation have still in dry season. The long-wave radiation increased 17 Wm$^{-2}$ within half a day, while the solar radiation was still in clear sky condition. The solar radiation flux decreased 83 Wm$^{-2}$ in the following 48 hour due to the happening of cloud, and then the rainfall weather was coming.

Annual range of the radiation flux

- Solar radiation Sd ranges 3 Wm$^{-2}$ to 334 Wm$^{-2}$, and the annual mean was 232 Wm$^{-2}$.
- Long-wave radiation Ld changes from 359 Wm$^{-2}$ to 452 Wm$^{-2}$, the range (93 Wm$^{-2}$, 22% of its annual mean) was much smaller the that of the solar radiation. Annual mean was 420 Wm$^{-2}$.
- The range of downward flux (Sd+Ld) was 332 Wm$^{-2}$ (438 Wm$^{-2}$ to 770 Wm$^{-2}$), the mean value was 652 Wm$^{-2}$.

Heat balance on dry season and rain season

<table>
<thead>
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<th>Unit: Wm$^{-2}$</th>
<th>Dry season</th>
<th>Rain season</th>
<th>Dry season</th>
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<tr>
<td></td>
<td>2/18-</td>
<td>5/15-</td>
<td>10/06-</td>
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<tr>
<td></td>
<td>5/14</td>
<td>10/05</td>
<td>2/06</td>
</tr>
<tr>
<td>Sd</td>
<td>279</td>
<td>-59</td>
<td>220</td>
</tr>
<tr>
<td>Ld</td>
<td>417</td>
<td>17</td>
<td>434</td>
</tr>
<tr>
<td>Sd+Ld</td>
<td>695</td>
<td>-41</td>
<td>654</td>
</tr>
<tr>
<td>S0-Sd</td>
<td>143</td>
<td>77</td>
<td>220</td>
</tr>
</tbody>
</table>

Acknowledgments

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References

Changes in boreal autumn rainfall in the recent 50 years (1961-2010) over the Indochina Peninsula
Climatological Onset Date of Summer Monsoon over Vietnam

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Summary: This study presents an attempt to investigate the summer monsoon onset date over Vietnam, especially for central coastal area, by using 5-day averaged rainfall, maximum temperature and minimum relative humidity observations at 54 selected meteorological stations in the region during the 1979-2003 period. The averaged conditions of this onset process are also examined by the NOAA satellite OLR (Outgoing Longwave Radiation) and horizontal winds, temperature, specific humidity and geopotential height at pressure levels from JRA25 reanalysis data. The result showed that the earliest onset is found in the northwestern mountainous region in late April. Later, the westerlies summer monsoon start dominating over the Indochina Peninsula in mid-May, bringing the rainy season in the Red river delta in the north and Mekong river delta in the south of Vietnam. In case of central Vietnam, which is very different from others, as a result of Foehn wind, from mid- to late May, sudden increase of temperature and gradual decrease of minimum relative humidity are indicted as summer monsoon onset date for this region. Over the Indochina and SCS (South China Sea) region, the most significant changes of convective activity and 850 hPa circulation fields occur in 28th pentad (16-20 May). Moreover, there is clear linkage between the beginnings of Meiyu season with the onset of summer monsoon in the SCS. In addition, in the upper atmosphere (200 hPa level), the retreat northward of sub-tropical westerly jet and the formation of TSE (Tropical Strong Easterly), consequence from the difference in heating over Indian inland and cooling over ocean, also play an important role in summer monsoon circulation.

Keywords: Summer Monsoon Onset, Tropical Strong Easterly, Meiyu Front, Vietnam

1. Introduction

In previous studies, the summer monsoon onset date in the Indochina Peninsula is determined in some various methods. Essentially, these methods are based on either precipitation or convective activity indicated by satellite observation [19, 11, 20, 23] or changes of the prevailing winds [14, 8, 21, 9] or combine both of them (Xie et al. 1998). The date of summer monsoon onset over the Indochina Peninsula was found in the early to mid-May [11, 20, 24] or in late April to mid-May [17]. However, by examined the features of rainfall distribution, [11] found that some stations in coastal region of Indochina, which is also the middle region of Vietnam, was not able to determine the onset by the criteria. Therefore, such stations were not considered (e.g. [20]) then the descriptions of summer monsoon onset in Vietnam are still insufficient. In the other hand, the definition of summer monsoon onset using the changes of prevailing winds (e.g. [9]) is only suitable for the south of Vietnam because in the northern and central, it is difficult to distinguish the monsoon from earlier dominated mid-latitude westerlies [11]. Thus the objective of this study is to investigate the summer monsoon onset date in Vietnam, including coastal area.

2. Data

The data used in this study are 5-day (pentad) mean of daily rainfall (P), maximum of temperature (Tmax), minimum of relative humidity (RHmin) are computed from daily observed data, which were provided from 54 meteorological stations over Vietnam by Vietnamese National Hydro-Meteorological Service (VNHMS) for the 25-year period (1979-2003). The homogeneity of the precipitation data from these stations is checked in Endo et al (2009). When missing data in a particular pentad exceeds 2 days, the data from this pentad will be removed from the calculation of the mean data. Subsequently, for investigating the general atmospheric circulation, mean pentad data of zonal and meridional wind components (U, V), temperature (T), specific humidity (Q) and geopotential height (H) at 8 pressure levels (1000, 925, 850, 500, 400, 300, 250, 200 hPa) are derived from 6-hour interval Japanese 25-year reanalysis data (JRA25) [13]. In addition, the convective activity is examined by the daily NOAA (US National Oceanic and Atmospheric Administration) OLR satellite observations [10]. The JRA25 and OLR data’s spatial resolution is 1.25° x 1.25° and 2.5° x 2.5°, respectively, and also has the same 25-year period as observed station data. Finally, the 30-second global elevation data from GTOPO30 of U.S. Geological Survey’s EROS Data Center (EDC) (http://www1.gsi.go.jp/geowww/globalmap-gsi/gtopo30/gtopo30.html) is used for the topography map of Vietnam (Fig. 1).

3. Determine the Onset of Summer Monsoon in Vietnam

Firstly, the summer onset date will be investigated by the definition proposed by [11]: “The first pentad when the mean precipitation exceeds annual mean pentad precipitation (Pm) in at least three consecutive pentads after lowering it in more than three consecutive pentads”.

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For reducing noise before applying that definition, the precipitation data is smoothed with a 1-2-1 filter (forward and backward) applied once in temporal dimension. As a result, Fig. 1 shows the onset date at the location of 54 meteorological stations over Vietnam. The earliest onset of summer monsoon in the late of April to early May (23rd pentad P23- 25th pentad P25) is located in the northwestern mountainous region. While, the later beginning is found in mid-May in the Red river delta in the north and Mekong river delta in the south of Vietnam (P26-P27). But for the coastal area in the central of Vietnam, the monsoon onset date is often indefinable. It is because of Foehn wind, as the consequence of summer monsoon, brought warmer and drier weather instead of rainy season to the middle of Vietnam during summer regime (Fig. 2). The wet southwesterly Asian summer monsoon, after blocking and lifting by the facing north-east Truong Son mountain range, drops most of its moisture on windward slopes of Laos and Cambodia, causes hot and dry conditions on the lee side of coastal area of Vietnam by diabatic heating.

Apart from the difference above, the results for the northern and the southern Vietnam are very similar to those obtained from the previous studies. According to [11], inland region of Indochina (Thailand) has the onset date in late April (P23-P24) which is earlier than coastal region. Such earlier onset occurs under mid-latitude wind system and could be call as “pre-monsoon rain” [11]. The onset date over the southern of Vietnam by daily mean zonal wind and accumulated amount of rainfall exceed 0.5 m/s and 5 mm, respectively, in at least 5 consecutive days [16]. Although by the different criteria, the result is also showed that the average onset date of the 26-year period (1979-2004) is the 12th May, which is also in P27.

Fig. 2 showed the difference between the two consecutive of 5-day Tmax from P22 to P33. As mentioned above, sudden increase of temperature and decrease of minimum relative humidity, as a result of Foehn wind, will be indicted as summer monsoon onset date for central Vietnam. Basically, Tmax has the most increase occurs in P23, P25 and P29. From P22 to P27, late-April to mid-May, while the temperature in the northwestern area does not change significantly with only mild decrease in P24, along with the significant increase of RHmin and P (Fig. 3), under the influence of summer monsoon onset in this area; the Red river delta temperature is increasing, as the result of change from winter to summer season. But in P28, the north and the middle of Vietnam is covered with the decrease of Tmax. In case of Mekong river delta, Tmax starts decreasing constantly from P26. This is related to the increase of rainfall in this region (Fig. 3) and it is clear that the signal of the transition from the dry season to rainy season brought by summer monsoon here. For the coastal region, the most significant increase of Tmax (about 2°C) happens in the P29. After P29, the temperature difference is not as significant as the previous period.

Fig. 3 indicate the difference of 5-day averaged RHmin and P. Over the north and the middle, in P23 and P25, although the minimum relative humidity decreases and temperature increases significantly, the amount of rainfall is still increasing from P23 - P24 and P27 – P28, after decrease in P25 and P26. It is because of in late winter, late-February to March, there are wet days with very light rains under the influence of the last cold fronts in the north of Vietnam [16]. Although these last cold surges are not strong enough to bring rainfall to the middle area, it still makes relative humidity increases there. In the late April to early May (P24-P26), the dominated mid-latitude westerlies over northern and central Vietnam before mid-April starts to retreat northward; moreover, the easterly trade wind associated with the western Pacific subtropical high, which dominates south of Vietnam, also retreats eastward to the western Pacific Ocean and replaced by the summer monsoon westerlies [5,11]. That retreat eastward of easterly trade, which represent by the increase of
westerlies over central Vietnam in P25 (Fig. 5), discontinue providing moisture to the northern and central Vietnam in P25 and P26, cause RHmin and P decreased and Tmax suddenly increased significantly in this time. However, from P27, in when the easterlies already move to the SCS and the summer monsoon westerlies start dominating the north and the middle of Vietnam, the relative humidity and rainfall changes to increase again, and therefore, we have the most significantly decrease of maximum temperature in P28 (Fig. 2). From P28, the monsoon strengthens and begins to bring hot and dry weather in the central Vietnam, represented by the increase significantly of temperature in P29 and the constant decrease of relative humidity from this time, indicted the summer monsoon onset date for this region. This result is agreed quite well with the previous study of [9] in which considered only the changes of direction of 850-hPa winds. Under the influence of Foehn wind, the meteorological stations in the central Vietnam recorded minimum relative humidity to being lower than 60% (data not shown). Meanwhile, in South Vietnam, from P25, the dominated easterly wind begins to weaken and completely succeed by the summer monsoonal southwesterly in mid-May, along with the significant increase of rainfall amount there (P27 to P28). After P28, the monsoon westerlies cover not only the Indochina Peninsula but also the SCS region.

Fig. 3. Same as Fig. 2 but for the minimum relative humidity (%, left) and amount of precipitation (mm, right).

4. Convective Activity and Atmospheric Circulation Related to Onset Period

a. The Convective Activity

To further elaborate on the field of convective activity, the pentad mean OLR distribution and difference between the two consecutive pentads from P22 - P30 over Indian, Indochina and the South China Sea area are also displayed in Fig. 4 and 5, respectively. In this study, the threshold value less than 240Wm-2 is used to indicate the strong convective activity [12]. While the SCS region still has the OLR value higher than 240Wm-2 until P28; from P23, whole region of Vietnam is under OLR value lower than that threshold, except in coastal area. The northwestern mountainous area has much stronger convective activity in P23, represented by the significant decrease of OLR value. Besides, it is noted that although the OLR value in the northwestern mountainous region of Vietnam is higher than that in the south, this region has earlier onset date. The replacement of mid-latitude and trade wind systems by westerlies summer monsoon in the Indochina Peninsula, starts from P25, enhances the convection activity both here and the SCS. As a result, from early to late-May (P26-P28), the OLR value in Vietnam and inland of the Indochina Peninsula gradually decreases. However, the OLR value in coastal area of Vietnam is still higher than 220 Wm-2. Therefore, it is clear that convective activity here is weak, indicating the effect of Foehn wind. The OLR value over the BOB (Bay of Bengal) and SCS region decrease significantly in P26 to P28; especially in P28, there are strong convective zones appeared along the southern coast of Thailand and BOB with OLR value lower than 200 Wm-2. And also from P28, the OLR value in the SCS area also begins to be below 240 Wm-2.

b. Low-Level Circulation and Linkage with the Beginning of Meiyu Season in SCS

At the 850-hPa level, over the Indochina Peninsula, the easterly trade wind dominates in 7.5° – 12.5°N while mid-latitude westerlies are located in the north of this wind system before P24 (late April). The retreat and replacement of those wind systems by the summer monsoon westerlies start from P25, represented by the strengthening of westerlies over Bengal Bay, south of Indochina and South China Sea area in P25 (Fig. 5). The southwesterly winds first expand northward in the BOB, cause the increase of convective activity there in P26 then merge into the mid-latitude westerlies to the north from P27, and it finally cover all over the Indochina Peninsula and SCS area in P28. Hence, the OLR value over the South China Sea region is only being below 240 Wm-2 after the western Pacific subtropical high move eastward and summer monsoon dominates there (Fig. 4). Over the SCS area, the significant strengthen of
westerly winds occur in P25, P27 and P28 (Fig. 5). While the increase of westerlies in P25, which was related to the retreat eastward of trade wind, happened all over the SCS area; that increase in P27 and P28 only appeared in the south SCS. Especially, in P28, there is strong acceleration of northeasterly winds over the north of SCS, south of China mainland and Taiwan. In the other hand, next to the south of this system, the area of significant increase of westerlies is located. Therefore, we have strong cyclonic development appear over SCS as well as Taiwan area. And vorticity value over the SCS area is also higher than 6x10^{-6}s^{-1} (Fig. 6). These behaviors, which are also observed by 1995), are referred to the Meiyu front, as defined by the axis of vorticity maximum. The arrival of Meiyu front in SCS is a possible mechanism that contributes to the triggering of the summer monsoon onset [2,1]. Moreover, [2,3] also considered 16 May (P28) is the start time of the first phase of Mei-Yu season over South China and Taiwan. Clearly, we have P28 is the most important pentad in changes of not only convective activity but also 850-hPa wind fields in the Indochina Peninsula and SCS region.

c. The Retreat of Westerly Jet Stream and Genesis of TSE

In the upper troposphere (Fig. 4), from P24 to P30, along with the movement towards the north of subtropical westerly jet stream, the Tibetan anticyclone also moves north-westward from south (10°N) to north (20°N) of the Indochina area. Around 10°N, the equatorward outflow from this anticyclone gains easterly angular momentum and appears as an easterly jet stream from P27 [6, Raghavan 1973). In the summer, the ocean is cold compared to its adjoining continental plains in the north, because of rainfall and cloudiness formation as a result of summer monsoon. While in the Indian inland the maximum heating taking place, especially over Tibet Plateau where the largest heating amount and trend are observed in the upper troposphere (Taniguchi et al 2011). This difference in heating and cooling and the ensuing pressure gradient is what drives this jet (Fig. 6). Therefore many scientists considered this well-known tropical jet stream is major component of summer monsoon circulation [3,7].

5. Conclusions

The onset date of summer monsoon in Vietnam is different from the north to the south. It was found that the earliest onset is in the northwestern mountainous region in late April. Such earlier onset occurs under mid-latitude wind system, could be call as “pre-monsoon rain” [11]. Later, the westerlies summer monsoon starts dominating over the Indochina Peninsula in mid-May, bringing the rainy season in the Red river delta in the north and Mekong river delta in the south of Vietnam. In case of the central of Vietnam, it is impossible to determine the onset
date by only considered the changes of precipitation. As a result of Foehn wind, from mid to late May, the suddenly increase significantly of maximum temperature and the decrease gradually of minimum relative humidity indicted the summer monsoon onset date for this region. These results are agreed well with the previous studies like [11, 20, 16, 9]. However, the observation information of Laos and Cambodia should be added to check the spatial distribution of rainfall and humidity in Indochina, especially for the windward side of Truong Son range. The analysis results of convective activity and atmospheric circulation fields over Indian, Indochina and the South China Sea area showed that P28 is the key pentad in the changes of not only convective activity but also 850-hPa wind fields in this region. Clearly, there is a linkage between the beginning of Meiuy season over South China and Taiwan with the onset of summer monsoon in Indochina Peninsula and SCS. In addition, in the 200-hPa level, the retreat northward of sub-tropical westerly jet and formation of tropic easterly jet, consequence from the difference in heating over Indian inland and cooling over ocean, also play an important role in summer monsoon circulation.

Finally, this study presents only averaged conditions of Vietnamese monsoon. In the future, the year to year variations should be investigated. Besides that, the reason of earlier monsoon onset in the northwestern and the mechanisms of Foehn wind in the central of Vietnam, which perhaps relate to topography and therefore could not be described by the coarse resolution of reanalysis data, are expected to be solved in further studies using regional climate models.

Acknowledgement

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References

Summer Monsoon Onset over Vietnam for the Period of 1961-2000 using RegCM4.2

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Summary: This study aims to investigate summer monsoon onset dates over Vietnam and surrounding regions using the Regional Climate Model version 4.2 (RegCM4.2) driven by the ERA-40 reanalysis data. Comparison of the 1960-2001 averages of wind fields at 200 and 850 hPa shows the consistency of RegCM4.2 with ERA-40. However, there are large differences in air temperature at the low level of 850 hPa, which are mainly attributed to the resolution difference between RegCM4.2 and ERA-40. Over Vietnam, monsoon onset date varies considerably among the regions. During the 1960-2001 period, the earliest onset generally occurs around April 15 in the western part of the Highland region and the latest onset occurs early June in the north. A long-term trend analysis shows that the monsoon onset dates over South Vietnam (North Vietnam) have shifted to approximately 0-10 days earlier (0-15 days later) in recent decades.

Keywords: Climate Change, Monsoon Onset, Regional Modeling, Vietnam

1. Introduction

Over the past recent decades, Asian summer monsoon (ASM) has become a critical issue in many studies. For example, [12] used the relative climatological pentad mean rainfall to describe the spatial–temporal structure of the Asian–Pacific summer monsoon rainy season. The results showed that monsoon rainfall first increases in the East Sea and then extends to the Pacific Northwest. The 850-hPa zonal winds averaged over the central East Sea (50–150N and 1100–1200E) was used by [13] in order to determine the monsoon onset dates for the period of 1948-2001. The earliest onset occurs in the 25th pentad (1-5 May) while the latest is in the 34th pentad (14-19 June) [13]. The onset of ASM as suggested by [1] occurs the earliest over the central and the southern regions of the Indochina Peninsula. The trends of ASM onset dates during the period of 1979–2008 were examined by [4]. The authors showed that monsoon onset occurred earlier over the Bay of Bengal and the western Pacific region due to the heat contrast between the Asian landmass and tropical Indian Ocean. The 850 hPa zonal wind data of the Coupled Model Inter-comparison Project phase 3 (CMIP3) was used by [3] to show that the onset dates over the Bay of Bengal, the Indochina Peninsula and the East Sea are projected to delay by 5 to 10 days in the end of the 21th century under the A1B emission scenario. One of the reasons for this change might due to the delay of the reversal of upper-tropospheric meridional thermal gradient between the Eurasian Continent and the north Indian Ocean.

Located in the eastern part of the Indochina peninsula, Vietnam is a country with tropical climate and complex topography. Given the strong influence of the ASM system, many socio-economic sectors of Vietnam such as forestry, fisheries and agriculture are strongly dependent on the monsoon activity. Therefore, it is of great importance to understand monsoon characteristics as well its impacts over Vietnam. However, knowledge gaps in the monsoon activity over Vietnam still remain large. Recently, [7] used daily rainfall at six stations in southern Vietnam and 1000 hPa reanalysis zonal wind data to determine the monsoon onset dates in Vietnam for 1979-2004. It is shown that the mean onset date is May 12, with the earliest onset occurred in 1979 (April 19) and the latest one occurred in 1993 (June 9). The authors also indicated that late (early) onsets over Vietnam are preceded in March-April by higher (lower) sea level pressure over the East Sea, stronger (weaker) southeasterly winds over southern Vietnam, decreasing (increasing) deep convection over the Bay of Bengal and the reverse situation over Indonesia.

To the best of our knowledge, previous studies have not considered yet the variability of monsoon onset dates over the different sub-climatic regions of Vietnam. This study will be a first attempt to depict those detailed features. In the next Sections, we will introduce a new set of criteria to calculate monsoon onset dates and apply those criteria to the output of the Regional Climate Model version 4.2 (RegCM4.2) [2]. The trend of onset dates for the period of 1960-2001 over Vietnam will be discussed.

2. Numerical Experiment and Onset Monsoon Index

a) Numerical Experiment

The domain size of RegCM4.2 extends from 95°E to 119°E and from 6°N to 29°N with a horizontal resolution of 20 km for both east-west and north-south directions. The 1960-2001 ERA-40 reanalysis data with horizontal resolution of 2.5°x2.5° and 6 hr time interval [11] are used as initial and boundary conditions for the experiment. Other physics options are similar to [8].
b) Onset Monsoon Index

To identify the monsoon onset for each model grid over Vietnam and the surrounding regions, a new set of onset criteria is defined as follows:

1) Daily zonal wind at 850 hPa (u850) is greater than 0.5 m/s and originally from the Bay of Bengal;
2) Daily zonal wind at 200hPa (u200) is less than 0 m/s; and
3) Criteria 1) and 2) are satisfied for at least 5 consecutive days.

3. Results

3.1. Model performance

Comparison of the 42 year averages (1960-2001) of air temperature and wind fields at 200 hPa for the two typical periods JJA and DJF shows the consistency of RegCM with ERA-40 in both spatial distribution and magnitude (Fig. 1). The Tibetan anticyclone at the upper level with the monsoon easterly jet in JJA over Vietnam is well reproduced. Some differences can still be detected in the boundary regions.

At 850hPa, there are more pronounced differences between RegCM4.2 and ERA40 (Fig. 2). With the resolution of 20 km, i.e. 10 times better than that of ERA-40, the RegCM4.2 experiment clearly shows the topography effect on air temperature at the low level, particularly over the Tibetan region and over the Indochina Peninsula during both DJF and JJA. Over Vietnam, RegCM4.2 amplifies the easterly wind during DJF while it slightly pushes the simulated JJA westerly jet more northward.

3.2. Monsoon Onset

Monsoon onset date varies considerably among the regions over Vietnam (Fig. 3). The earliest onset date occurs in the western part of the Highland region in the end of April. The mean onset date is around May 15-20 in the South and Central Vietnam. The monsoon continues to expand northward and the onset is around May 25 – June 5 in the Northern part of Vietnam.

To examine the monsoon onset variability, we selected two equal periods: 1960-1979 and 1980-1999. The monsoon onset dates over South Vietnam have shifted to approximately 0-10 days earlier in recent decades (Fig. 4). In contrast with the Southern region, the onset dates have shifted to 0-15 days later over North Vietnam.

To examine the monsoon onset variability, we selected two equal periods: 1960-1979 and 1980-1999. The monsoon onset dates over South Vietnam have shifted to approximately 0-10 days earlier in recent decades (Fig. 4). In contrast with the Southern region, the onset dates have shifted to 0-15 days later over North Vietnam.

The non-parametric Mann-Kendall test [6] is used to examine the trend-significant level for the onset series (x1, x2, ..., xn) where xi represents the onset date of year i. Trend’s value (Q) is estimated using the Sen’s method where Q is the median of the series composed of n(n-1)/2 elements { , k=1,2,...,n-1; j>k} [10]. Fig.5 confirms the findings in Fig.4, with earlier onset in the southern regions and later onset in the North. However, the trends are only

Fig. 1. 1960-2001 average wind and temperature at 200hPa from ERA-40 (top) and RegCM (bottom) simulation in DJF (left) and JJA (right).
Fig. 2. As Fig. 1 but for 850 hPa.

Fig. 3. Average monsoon onset date for the 1960-2001 period. Days are counted from April 1st.

Fig. 4. Difference in the monsoon onset between 1980-1999 and 1960-1979. Units in days.
significant over North Vietnam and over the southwest part of the East Sea. A possible factor of the advanced large-scale monsoon onset is likely to be attributed to the heat contrast between the Asian landmass and the tropical Indian Ocean [4].

4. Conclusions

The new set of monsoon onset criteria has been applied for the RegCM4.2–ERA40 simulation. Taking the 42 yr averages (1960-2001), it was shown that the earliest onset in Vietnam generally occurs around April 15 in the western part of the Highland region and the latest onset occurs early June in the north. Advanced (delayed) monsoon onset over South Vietnam (North Vietnam) is detected with significant trends over North Vietnam and over the southwest part of the East Sea. Further investigations in the near future are needed to elucidate the possible mechanism that produces the opposite onset trends in North and South Vietnam.

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References

Observed Change in Climate Extremes in Vietnam

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Abstract

Viet Nam lies to the south east of the Asian continent. The mainland territory of Viet Nam covers an area of about 329,000 square kilometers. The geographic coordinates of Vietnam consist of latitude 102° 08' - 109° 28' east and longitude 8° 02' - 23° 23' north. It is bordered with China in the north, Lao PDR and Cambodia in the west.

Consequences of climate change in Vietnam are considered to be serious and present significant threats to hunger eradication and poverty reduction, the achievement of the Millennium development goals, and country’s sustainable development. Most vulnerable sectors and regions to climate change are water resources, agriculture and food security, public health, deltas and coastal areas. It can be said that understanding of climate change effect, especially climate extremes events is very important due to the potentially high social, economic and ecological impacts of such events.

The aim of this paper is to represent the observed changes in climate extreme in Vietnam. Our analysis indicated that changes of climate extremes and sea level have the following noticeable features: (1) Over the past 50 years, annual average temperature has increased about 0.5 to 0.7°C; (2) Typhoon trajectory moves southward and typhoon season shifts to later months of the year and there were more typhoons with high insensitive; (3) Number of drizzle days decreases significantly; (4) Frequency of cold front in the North decreases significantly in the past three decades and number of extreme cold spell decreases, however, in some years it prolongs with historical insensitive, e.g. in 2008; (6) Number of hot wave is more in the period of 1991 - 2000, especially in the Central and South; (5) Rainfall increases in rainy season (Sep. to Nov.) causing more frequently severe floods in the Central and Southern Viet Nam, however, it decreases in dry season (Jul. to Aug.) causing droughts every year in most regions of the country; and off-season extreme rainfall events occur more frequently. (6) ENSO has stronger effects on weather and climate in Viet Nam. Based on this study, we can conclude that climate change has significantly effect on change in climatic extremes in Vietnam during the second half of the 20th century.
Abstract

Global warming brings direct and indirect effects to climate change that might threats productivity of agricultural crops. BMKG has some activities in supporting agricultural sector such as carry out climate dissemination by making applicable products that are automatically updated as well as could be accessed online from android. The information that is provided such as seasonal onset, starting date of planting term, drought, and chance for commodities.

The technical corporation between BMKG and JICA regarding the vulnerability in agricultural sector due to climate change had a pilot project in Bali started from year 2011 run until 2013. This activity produces a map and a guideline about the vulnerability of agricultural sector assessment to climate change. BMKG has a purpose to build a CEWS system for agricultural sector based on it’s experienced in making DEWS for water resource sector collaborated with the Ministry of Public Works. In DEWS, there is an information system using dual server both in BMKG and in The Ministry of Public. Share the components such as data, jobs, and the output model synchronize are always between these two ministries. The same system might be applied in agricultural sector in order to support the process of Crop Calendar. In addition, BMKG also placed climate agriculture (agro climate) monitoring tool, which is AAWS that are distributed in some provinces of rice sources (11 main provinces plus 7 secondary provinces). Moreover, there is SLI and some DEWS outputs are also displayed namely SPI (Index Period System), deficit, etc. By an adequate climate information system, hopefully a processed could be delivered to support the national food security.
Future Change of Pressure Patterns during Extremely Hot Temperature Events in August in Japan Predicted by MRI-AGCM3.2H

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Keywords: Extremely Hot Temperature, Pressure Pattern, Pacific High, Tropical Cyclone

1. Introduction

In recent years, global warming has advanced due to the emission of greenhouse gases and extremely hot temperature events have often occurred all over the world [1]. In Japan, for example, many people died in August 2010 because of severe heat waves. The Pacific high can have a great influence on monthly or seasonal temperatures in Japan [2]. On the other hand, extremely hot temperature often last for only a few days. Several pressure patterns can bring about such short-time extremely high temperatures. For instance, when the Pacific high is weaker than the normal and a low pressure (or a typhoon) is located in the Japan Sea, an extremely hot temperature event occurs due to warm advection to Japan. There have been few studies about future changes of pressure patterns causing such an extremely hot temperature event with a duration period of only a few days.

In this study, we examine future changes in pressure patterns around Japan and their frequencies during extremely hot temperature events in August in Japan with global warming.

2. Data and Method of Analysis

We use daily mean surface air temperature and sea level pressure (SLP) data in August predicted from 1872 to 2099 by MRI-AGCM3.2H, which was constructed at the Meteorological Research Institute in Japan. The horizontal resolution is about 60 km. As the boundary condition, the observed sea surface temperature (SST) having its interannual variability by the Hadley Center (HadISST) [3] is used in the reconstructed experiment (from 1872 to 2005). On the other hand, the SST predicted in the future experiment (from 2006 to 2009) is estimated by the CMIP3 multi-model ensemble mean to which the detrended interannual variabilities in the HadISST are added. The future experiment is based on the SRES A1B scenario. The simulated data consist of four ensemble members by slightly changing an initial atmospheric condition. The period analyzed in this study is from 1979 to 2003 and from 2075 to 2099 (hereafter called “present experiment” and “warming experiment”, respectively).

Thus, there are 31 days x 25 years x 4 ensemble = 3100 days for each period. For the purpose of verifying whether the results of analysis in MRI-AGCM3.2H are consistent with that in observation data, we analyze SLP data in JRA-25 [4] (from 1979 to 2003).

EOF analyses are conducted to categorize the pressure patterns in SLP over 20ºN to 60ºN, 120ºE to 160ºE in each of the warming experiment and the warming experiment. We divide Japan into two regions (Fig. 1). For each of the regions, an extremely hot temperature event is defined as being above the 90th percentile temperature of each period of the two experiments and JRA-25. Thus, the total number of days about the extremely hot temperature event is 310 days and 77 days in the experiment and JRA-25, respectively. Composite SLPs in the extremely hot events for each region are calculated when the absolute value of the time coefficient in each EOF mode is above the +1 standard deviation (It means that its mode is dominant).

3. Results

As an example, part of the results for the 1st EOF and the 2nd EOF are described below. Fig. 2 show the 1st EOF and the 2nd EOF in the present experiment, which represent variabilities of pressure centered north of Japan and south of Japan, respectively. The distributions and contribution rates of these EOFs are similar to that in JRA-25.

Fig.3a shows a composite SLP for the extremely hot temperature events in the Southern Japan when the time coefficient in the 1st EOF is below the -1 standard deviation. An expansion of the Pacific high is weak and a relatively strong low pressure is located north of Japan. The number of days for this pattern in the present experiment is 71 days, which is about 23 % of all extremely high temperature events. In JRA-25, the number of days is 17 days (about 22%). Fig. 3b is the same as Fig. 2b except that the EOF is the 2nd mode. The Pacific high does not cover Japan and a tropical cyclone is located south of Japan. The number of days for this pattern in the present experiment is 38 days (about 12 %). On the other hand, the number of days in JRA-25 is 3 days (about 4 %).

Fig.4 displays the future change of the composite SLPs for the extremely hot temperature events in the Southern Japan when the time coefficient in the 1st and 2nd
Fig. 1. Definition of the Northern Japan and the Southern Japan

Fig. 2. (a) The 1st EOF and (b) the 2nd EOF for the SLP in August over 20°N-60°N, 120°E-160°E in the present experiment. Units are hPa.

Fig. 3. (a) Composite SLP pattern for the extremely high temperature events in the Southern Japan when the time coefficient in the 1st EOF is below the -1 standard deviation in the present experiment. (b) Same as in (a) except in the 2nd EOF. Shading indicates an anomaly from the 25-year mean field. Units are hPa.

Fig. 4. (a) Difference of the composite SLP for the extremely high temperature events in the Southern Japan between the present experiment and the warming experiment when the time coefficient in the 1st EOF is below the -1 standard deviation. (b) Same as in (a) except in the 2nd EOF. Units are hPa.
EOFs is below the -1 standard deviation, respectively. In the 1st EOF, both the Pacific high and the low pressure become weak and the number of days increases to 96 days (about 31%). In the 2nd EOF, on the other hand, the Pacific high weakens and the tropical cyclone shifts eastward. The number of days increases to 55 days (about 18%).

4. Conclusion

There are many extremely hot temperature events in Japan when a tropical cyclone is located south of Japan or a developed low pressure exists over the continent. For the Southern Japan, these days increase with global warming. This suggests that an extremely hot temperature event may tend to occur more frequently in the future even if the Pacific high does not expand to Japan.

Acknowledgement

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References


Fundamentals of Field Monitoring System (FMS) in Asian monsoon region
Investigating Potential Relationships between Climate Change Impacts and Rice Production in the Philippines

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Summary: Previous statistical studies on the relation of climate and agriculture have emphasized on the impact of daily mean temperature and precipitation on rice yield on a global scale. In this study, we focus on analyzing climate change impacts in terms of key climatic variables that may affect rice production in the Philippines. Among the available data for the different climate factors, five were chosen according to statistical significance for the data set on the selected time period, 1970-2010, and they are as follows: minimum temperature, maximum temperature, precipitation, wet day frequency, and potential evapotranspiration. The analyses involved in this study are influenced by information on crop and climate dynamics but mainly focus on statistical analyses. Results show that the effects of climate change to crop production vary in different parts of the country. This is potentially due to the dissimilarity in climate characteristics among the different locations. Beyond looking at general climatic changes and analyzing crop production in the Philippines, further attention is given to the current leading rice producers in the country. The top ten rice-producing provinces: Nueva Ecija, Isabela, Pangasinan, Iloilo, Leyte, Camarines Sur, Tarlac, North Cotabato, Maguindanao generate 46% of the country’s harvest (as of 2009) and therefore, the effects of climatic changes and variability on these provinces in the future may greatly influence food security in the Philippines.

Keywords: Climate Change, Climate Variability, Rice Production, Food Security, Statistical Analysis

1. Introduction

Climate change and agriculture are interrelated processes, both of which take place on a global scale [4]. Future crop yields will be influenced by complex interactions between the effects of increases in atmospheric concentrations of gases as well as the effects of temperature and other climate variables brought about by climate change [5]. A study on the global scale climate-crop yield relationships [6] show occurring negative impacts of existing climate trends on crop yields at the global scale. Global climate change, in the form of rising temperature and altered soil moisture, is projected to decrease the yield of food crops over the next 50 years [7]. The six most widely grown crops in the world are wheat, rice, maize, soybeans, barley and sorghum [6]. Among these, rice plays a central role in feeding more than 3 billion people, including most of the world’s 1 billion poor, and any significant negative effect on rice production caused by climate change would be devastating for efforts to achieve global food security and address poverty [2]. World rice production must increase by ≈1% annually to meet the growing demand for food that will result from population growth and economic development [11]. However, an International Food Policy Research Institute (IFPRI) study forecasts a 15% decrease in irrigated rice yields in developing countries and a 12% increase in rice prices as a result of climate change by 2050. Thus, the effects of climate change on rice grain production pose a threat on global food security and poverty.

Since recent studies have highlighted the significant consequence of the increase in minimum temperature [3, 8, 9, 10], it is crucial to learn more about the potential direct effects of the changes in minimum temperature food production. There have been statistical studies in the past about the relationship of climate change and agriculture [5, 6, 12, 13] but most of them are on a global scale focusing on the impact of daily mean temperature and precipitation on rice yield. In this study, we focus on analyzing climate change impacts in terms of key climatic variables that may affect rice production in the Philippines. Specifically, the available data for these chosen factors are minimum temperature, maximum temperature, precipitation, wet day frequency, and potential evapotranspiration and we study these variables for the period of 1970-2010. We investigate the potential implications of changes in these climate variables to rice production in the top ten rice producing provinces in the country.

2. Methodology

Rice yields and area harvested for 1970-2009 in the three main islands and for each province were obtained from the Bureau of Agricultural Statistics. At 0.5° × 0.5° for the same time period, we obtained from the Climate Research Unit (CRU TS 3.1) [14] gridded monthly climate variables as follows: minimum temperature, maximum temperature, diurnal temperature range, daily mean temperature, precipitation, wet day frequency, vapour pressure, cloud cover, and potential evapotranspiration. Using multiple regressions, the relationship of the mentioned variables to the rice yield are studied at the national and regional level. Multiple permutations between the climate variables are regressed to identify which variables have the most impact of rice production. More than the previously established effects of minimum temperature on crops, the goal of this study is to investigate the potential implications of the changes in other climatic variables on rice production.
The analysis of these regressions will allow preliminary relational associations of each variable and combinations of these to the amount of rice production. The analyses involved in this study are influenced in general by information on dynamics of crop and climate but will be mainly statistical analyses and deriving relationships between the variables.

3. Results and Discussions

Fig. 1 shows the Annual Rice Yield in the Philippines from 1970 to 2009. The marked years namely 1972, 1983, 1987, 1993, 1998 and 2009 are the years where significant decline in production were observed. Based on gathered data, the mentioned years coincided with a combined increase in minimum temperature, maximum temperature and potential evapotranspiration.

After performing multiple regressions on the following predictors: minimum temperature (tmn), maximum temperature (tmx), precipitation (pre), wet day frequency (wet), and potential evapo-transpiration (pet) with the rice yield as dependent variable, results show that the effects of climate change to crops vary in different parts of the country. Further, the climate variables affect yield differently depending on the scale chosen (National, Island Groups, or Provincial). This is potentially due to the dissimilarity in general climatic characteristics among the different locations.

At the national scale, maximum temperature has the most negative effect while minimum temperature has the most positive coefficient in the equation formed from the regressions. These coefficients indicate the possible relationship between the yield and climatic variable, whether positive (increase in yield) or negative (decrease in yield). Considering the major island groups, Luzon, Visayas and Mindanao, results show that consistent with the analysis at the national scale, Luzon and Visayas are also negatively affected by increases in maximum temperatures. Mindanao on the hand appears to be positively influenced by all five variables. Multiple regressions on the provincial scale showed varying order of coefficients from the most negative to the most positive. Six out of the ten top rice-producing provinces are in Luzon while two are in Visayas and the other two are in Mindanao. Summary of the signs of coefficients for the different regressions is summarized in the map shown in Fig. 2.

We further analyze the relationships during El Niño, La Niña, and normal years. Tables 1 and 2 illustrate in summary, for particular provinces, the potential impact on rice production of the most influential variable. Table 1 for Nueva Ecija as an example shows that maximum temperature is beneficial (positive coefficient) during La Niña and normal years. However, maximum temperature affects yield negatively for El Niño years. Existing trends in these years show increasing value of maximum temperature for La Niña and normal years and decreasing values during El Niño years. These trends are actually good for crops in Nueva Ecija (not considering threshold values). Pangasinan, on the other hand, see Table 2, show negative coefficients for precipitation that imply that an increase in the amount of rainfall would affect the yield negatively. And the general trends for the different years appear to indicate an increase in precipitation. Hence, this can potentially lead to a decline in rice yield.

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Fig. 1. Annual rice yield in the Philippines from 1970 to 2009 (Data taken from the Bureau of Agricultural Statistics).
Fig. 2. Map summary of the positive and negative effects of climate variables to rice yield minimum temperature (tmn), maximum temperature (tmx), precipitation (pre), wet day frequency (wet), and potential evapo-transpiration (pet)

Table 1. Summary of maximum temperature for Nueva Ecija.

<table>
<thead>
<tr>
<th>Climate Type</th>
<th>Province</th>
<th>Years</th>
<th>tmx (°C)</th>
<th>Regression coefficient</th>
<th>Trend</th>
<th>Potential impact to yield</th>
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<td>La Niña</td>
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<td>Normal</td>
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Table 2. Summary of precipitation for Pangasinan.

<table>
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<th>Climate type</th>
<th>Province</th>
<th>Years</th>
<th>tmx (°C)</th>
<th>Regression coefficient</th>
<th>Trend</th>
<th>Potential impact to yield</th>
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<td>Pangasinan</td>
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<td>↑</td>
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<td>bad</td>
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<td>La Niña</td>
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<td></td>
<td>Normal</td>
<td>↓</td>
<td></td>
<td></td>
<td>bad</td>
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[14] BADC (British Atmospheric Data Centre) CRU TS 3.1 Gridded Data Available from: http://badc.nerc.ac.uk/
Assessing Climate Change Impacts on Crop Productivity in Selected Rice-Growing Areas in the Philippines

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Summary: Climate change directly affects rice production in the Philippines since it is highly dependent on climatic variables such as temperature, precipitation and solar radiation. Any changes in these variables have an effect on crop growth and development. This study assessed the effect of climate change and variability on rice yields in selected locations in the Philippines, namely: Bukidnon, Agusan del Norte and Benguet. Time series data of historical (baseline) weather and downscaled climate projections centered on 2020 (2006-2035) and 2050 (2036-2065) using regional climate model PRECIS were analyzed. Bias correction was done on the downscaled projected climate data of temperature and precipitation since they are either underestimated or overestimated by PRECIS. Hargreave and Samani equation was used to estimate solar radiation since historical data nor projections of solar radiation are not available. Analyses show that projected climate change and variability differ across locations. Increases in monthly means of maximum and minimum temperature are expected in 2020 and 2050 across the selected locations. Decreases in the amount of monthly mean rainfall and increases in monthly means of solar radiation are expected in Bukidnon and Agusan del Norte in 2020 and 2050. The opposite is projected in Benguet in both periods. Assessment of the effect of climate change and variability on rice production was facilitated using the Decision Support System for Agrotechnology Transfer (DSSAT) CERES-Rice simulation model. Rice yields for each location were simulated for the baseline condition, and for climate projections in 2020 and 2050, and analyzed using descriptive statistics, probabilities of yields, and percentage change in crop yields. Rice yields in Bukidnon and Agusan del Norte are expected to decrease in 2020 and 2050, while rice yield is expected to increase in Benguet. Average change in rice yields in Bukidnon is -8.09% and -13.46% in 2020 and 2050, respectively, while -12.94% and -19.13% in Agusan del Norte in 2020 and 2050, respectively. On the other hand, rice yield increases of 151.35% in 2020, and 143.16% in 2050 are expected in Benguet. Results show that climate change will result to expected reduction in rice crop productivity in low lying areas, and thus threatens food security. Location-specific adaptation measures are therefore imperative to reduce the adverse impacts of changing climate.

Keywords: Climate Projections, Crop Model, Yield Probabilities

1. Introduction

Climate and weather play an important role in crop production since weather and climate variability affect crop growth and development, define crop productivity, and also determine the cropping season [18, 16, 26]. An objective and science-based assessment of the effects of climate variability on crop productivity provides a systematic evaluation of the vulnerability and risk of crop production due to climate variability [15]. In recent years, advances in information and communication technologies as well as in various scientific disciplines have accelerated the integration of information and the generation of new knowledge using systems research tools such as process-based crop simulation models [18] geographic information system (GIS), remote sensing (RS), optimization techniques, geographic positioning system (GPS), and database management.

Climate change is a global phenomenon that is now a reality but whose effects and impacts are felt locally. It is expected to have profound impacts on water and food, biodiversity, health and many other sectors. Food security and agriculture are the most affected sectors of climate change. As agriculture depends on the climatic parameters like temperature, precipitation and solar radiation, any change on these parameters directly affect agriculture and also affects food security of a nation.

Among agricultural crops, rice (Oryza sativa L.) is one of the most affected by climate change and variability as well as by other natural disasters occurring in the Philippines. The occurrence of El Niño Southern Oscillation (ENSO), La Niña event, and other natural phenomena had adverse impacts on Philippine agricultural production since they are often associated with significantly large crop losses.

This paper aims to assess the effects and impacts of climate change and variability on rice productivity in selected locations in the Philippines, namely: Bukidnon, Agusan del Norte, and Benguet. These rice growing areas represent different agro-ecological environment, climate conditions, and elevation. Climate projections for the different locations for the historical (baseline) period, and for the future periods, the objective approach used in assessing the effects and impacts of climate change on rice productivity are presented.

2. Climate Projections

Projections for future climate were developed under different scenarios using the general circulation models (GCMs) [11, 12]. GCMs indicated that increasing concentrations of greenhouse gases (GHGs) significantly affects climate at the global and regional scales. However, GCMs are not directly useful for local level impact assessments of climate change and climate variability due to their coarse spatial resolution [12]. Downscaling procedures are therefore needed to derive the local-scale surface weather conditions given the regional-scale
atmospheric predictor variables used in the global and regional scale models. That is, downscaling climate projections is a method used to obtain high-resolution climate information at the scale of 50 km, by 50 km or less from the relatively coarse-resolution global models such as the GCMs.

GCM projections have to be downscaled using downsampling procedures such as the dynamical downscaling method, and the statistical downscaling technique. Dynamical downscaling method uses limited-area, high-resolution model such as regional climate models (RCMs) driven by boundary conditions from a GCM, to derive smaller-scale information. An example of a dynamical downscaling approach is the PRECIS (Providing Regional Climates for Impact Studies) model used by PAGASA in 2011 to generate climate projections for different provinces in the Philippines. However, a regional climate model such as the PRECIS is computationally demanding and requires intensive training on the use of the model.

Statistical downscaling technique involves determining statistical relationships between observed small-scale variables and larger (GCM)-scale variables using either analogue methods, regression analysis, or neural network methods. Future values of the large-scale variables obtained from GCM projections of future climate are then used to derive the statistical relationships and to estimate the smaller-scale details of future climate, i.e. quantitative relationships are derived between GCM as predictors and local climate variables as predictands.

For the Philippines, the so-called A1B climate scenario is the more plausible scenario considering the rate of development and level of adaptation [18]. Using the A1B climate scenario for 2020 (2006-2035) and 2050 (2036-2065), PAGASA downscaled the projected weather data using the PRECIS model for selected locations.

Observed weather data for the baseline period, and climate projection data in selected locations (Bukidnon, Agusan del Norte, and Benguet) were gathered from PAGASA. These datasets include minimum temperature, maximum temperature, precipitation, and solar radiation. Downscaled data from PRECIS model were subjected to bias correction. Bias correction was done to temperature and precipitation data for projected climate from 2006-2035, and from 2036-2065. Since solar radiation data are required as input to crop simulation model but are not available for both the observed historical series and the climate projections, it has to be estimated using Hargreave and Samani equation (2003) based on temperature data.

3. Crop Simulation Model

A process-based crop simulation model may be used to estimate crop yield as a function of weather conditions, soil conditions and crop management scenarios [18]. Crop-Environment Resource Synthesis (CERES-Rice) model under the Decision Support System for Agrotechnology Transfer (DSSAT) version 4.0.1 was used. The crop model was calibrated using the set of crop genetic coefficients of a standard rice variety (IR64) under Los Baños conditions. Rice crops yields were simulated under different sets of weather data during the historical period (baseline) and the projected climate for years centered on 2020, and 2050 for specified planting dates. Simulated crop yields under different climate conditions were analyzed and compared in terms of descriptive statistics, probability of exceeding specified yield levels, and percent change in yields.

The DSSAT CERES-Rice model has also been extensively validated in several locations for a standard rice variety IR72 and IR64 [18, 16]. The model can be used to simulate crop yields under different crop production systems as well as crop management regimes including varying planting dates.

4. Results and Discussion

There are growing global and local observational evidences that demonstrated that climate variability has changed based on empirical distributions of observed or historical data of rainfall and temperature in selected locations. Long sequences of reliable historical datasets have shown statistically significant changes in terms of distributions such as increase in mean level, variability and extreme values.

Historical (baseline) weather data and climate projections for periods centered on 2020 and 2050 using the regional climate model PRECIS were analyzed and compared. Fig. 1 through 3 show the comparisons of the monthly average rainfall and average maximum rainfall for selected locations. Results indicate that the effects of climate change vary from location-to-location. Monthly rainfall will generally decrease. However, daily rainfall in Bukidnon will be more intense. On the other hand, changes in monthly rainfall distribution in Agusan del Norte vary among months within the year but more intense daily maximum rainfall events are expected in the future. For high elevation areas in the Philippines such as Benguet Province, climate change is expected to bring increased monthly rainfall as well as more intense maximum daily rainfall which may trigger more landslides and accelerate soil erosion in watersheds. Downscaled rainfall data for climate projections in the three locations, indicate that rainfall events with magnitudes much higher that the maximum historical records may occur. These extreme events will change the hydrologic regime of floods in these areas.

While the amount of rainfall is expected to decrease in Bukidnon and Agusan del Norte while increase in Benguet, the number of dry days is expected to be more frequent. Moreover, bias corrected downscaled weather data series from PRECIS model show that the projected climate in 2020 and 2050 is expected to result to increased minimum and maximum temperature for the three provinces. Days that have maximum temperature greater than 35°C is more frequent in Bukidnon and Agusan del Norte in 2020 and 2050. Based on Hargreave and Samani equation for estimating solar radiation, solar radiation is expected to increase in 2020 and 2050. These meteorological variables that determine crop photosynthetic processes will affect crop growth and development, and also crop productivity.

Using the DSSAT CERES crop model locally calibrated for IR-64 rice variety, rice crop yields for
baseline climate and projected climate in 2020 and 2050 were simulated with the appropriate weather data as inputs, and crop management parameters (e.g. planting dates). Results of simulations show that rice yields under baseline and projected climate scenarios showed varying trends depending on locations. Simulated rice yields during the baseline period and future time periods 2020 (2006-2035) and 2050 (2036-2065) were then compared using its descriptive statistics and yield probabilities. In Bukidnon and Agusan del Norte, mean rice yields during baseline period are higher than rice crop productivity during projected climate in 2020 and 2050. On the other hand, mean rice yields in Benguet during the baseline period were lower compared to the mean rice yields expected under the projected climate.

Estimated probabilities of exceedance of rice yields show that yields under projected climate scenarios were lower than that of the baseline period for specified level of probabilities in Bukidnon and Agusan del Norte. While some yield exceedance probabilities may overlap, still yield probabilities tend to be higher under baseline than the future period. However, the opposite is observed in Benguet where rice yield probabilities were lower during the baseline period than the future climate in 2020 and 2050.

Fig. 4 summarizes the effects of baseline and projected climate on rice yields in the locations studied. Results indicate that rice productivity may decrease in low lying areas but is expected to increase in high elevation areas like Benguet. In Bukidnon, the reduction on rice yields for 2050 is expected to double than the average reduction in 2020 during the weekly planting dates on second quarter. An average yield reduction of -6.47% in 2020 is expected to increase by almost two-folds (by -12.64%) in 2050. On the other hand, for Agusan del Norte, rice yield is expected to reduce by -9.71% and by -14.29% in 2020 and in 2050,
respectively. The average yield reductions during second and fourth quarter planting dates were higher in Agusan del Norte than in Bukidnon. On the other hand, planting date during the fourth quarter has higher average yield reduction with -15.52% and -23.73% for 2020 and 2050, respectively, than the second quarter with -10.36% and -14.53% for 2020 and 2050. Such yield reductions may be expected to have profound impacts on rice production in these areas.

On the other hand, Benguet which is located in higher elevation has cooler temperature. Even though increases in temperature are expected in 2020 and 2050, there is no recorded day that projected climate will have temperature exceeding 35oC. This climate condition favors the growth and development of rice (IR64) in Benguet. There is an average yield increase in rice yields in 2020 and 2050. During the second quarter, rice yields are expected to increase by 65.40% and 82.68% in 2020 and 2050, respectively. Likewise, during the fourth quarter, rice yields are also expected to increase by 237.30% and 203.64% in 2020 and 2050, respectively. Thus, rice production in high elevation areas is expected to benefit from climate change due to increased temperature which is favorable to the crop.

5. Concluding Remarks

Weather and climate are important factors in crop production especially under rainfed conditions. Thus, climate change which is characterized by increase temperature, changes in rainfall patterns and distribution as well as other climatic variables that determine crop growth and development will affect crop production.

Future climate projections have to be downscaled to specific areas to be useful for impact assessment studies. A number of approaches for downscaling may be applied depending on data and facilities availability and expertise needed. These include using a dynamical downscaling model such as the PRECIS used in this study, and also the statistical downscaling method (SDSM) which also yield reasonably reliable results (Lansigan, 2012). Moreover, an eco-physiological process-based crop model to simulate
crop yield under different climate conditions also offers an objective approach to evaluate quantitatively the effects and impacts of climate change and variability on crop yields. The objective evaluation shows that the extent of effects and impacts vary across locations with some areas adversely affected with reduced crop productivity while some areas (in high elevation) benefited by climate change with increase crop yields. The varying effects and impacts across locations with different agro-ecological conditions suggests that location-specific climate adaptation measures are imperative to minimize, if not eliminate, the adverse effects and impacts of climate variability and climate change on agricultural production, and better cushion the threat to food security. Knowledge- and science-based adaptation strategies are needed in managing climate risk. Recent advances in science and technologies offer opportunities to better integrate scientific knowledge available, local observations and datasets generated, and site-specific experiences that enhance climate resilience of local communities and local government units.

5. References


Potential Applications of the Field Monitoring System (FMS) for Local and Farmer-Level Climate Change Adaptation in Agriculture

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1. Introduction

The field monitoring system (FMS) was originally designed under the GRENE-CAAM project as a weather monitoring and soil sensing system in the field. The database from the selected sites in Monsoon Asia will be fed into a regional model to assess climate impacts in agriculture at the regional scale.

Assessing the capability of the FMS set-up in Nueva Vizcaya, Philippines, we have proposed in this paper the possible and potential applications of the system for local and farmer-level climate adaptation.

With the versatile features of FMS: (1) highly mobile and portable (can be installed easily in undifferentiated high elevations); (2) less expensive than permanently installed weather monitoring systems; (3) allows for internet-based “distant-access” data download; (3) dynamic and open system (additional features and sensors can be added easily when needed); and (4) almost maintenance-free, it can be used to delineate weather variations between small areas within a watershed.

An excellent agricultural and forest area where the FMS has great potential is the province of Nueva Vizcaya. Nueva Vizcaya has three climatic patterns (Fig. 1) – Type I in the western side, Type III in the central part, and Type IV in the eastern side. The eastern part of the province is the major source of highland vegetables, the area being blessed with a cooler climate because of its elevation. The central part, which is predominantly plain to slightly rolling area are rice and corn areas. Owing to its plain landscape, the central part of the province is the major built-up and commercial areas. The eastern side, mountainous and a part of the Sierra Madre watershed, is the source of citrus and other fruit crops. Citrus cultivation is the major agricultural industry in Nueva Vizcaya, dubbed as the “Citrus capital of the Philippines”.

The great climatic variability in the province is dictated by the differences in elevation due to the presence of the mountain systems. The long history of agricultural adaptation and indigenous knowledge of farmers has led to the present cropping systems found in the province.

Currently, due to insufficient instrumentation in the province, no hard data is available, particularly in the high elevated areas due to inaccessibility. A synoptic station is maintained through a long-term collaboration between the Philippine Atmospheric, Geophysical, and Astronomical Services Administration (PAGASA) and NVSU. The station is installed inside the Bayombong campus of NVSU in the central part of the province. A ten-year rainfall data from the synoptic station is summarized in Fig. 2.

3. Mobilization and Operationalization of the Field Monitoring System in the Philippines

The first FMS in the Philippines was operationalized in December, 2011 after a memorandum of understanding (MOU) between the Graduate School of Agricultural and Life Sciences, University of Tokyo, and Nueva Vizcaya State University (NVSU) has been finalized. The MOU stipulates an agreement of both parties in promoting closer cooperation and exchange of information pertaining to the agricultural informatics sector on the basis of equality, reciprocity, and mutual benefits.

The FMS is currently maintained inside the NVSU central experiment station in Bayombong, Nueva Vizcaya, Philippines (16.483° N, 121.150° E) which is in the central and plain area of the province. Initial training of researchers on FMS operation, management, and maintenance have been conducted during the last part of 2011.
The second FMS is expected to be installed in the town of Kayapa (16.4167° N, 120.9167° E), a mountainous town in the western part of the province primarily the source of highland vegetables.

4. Potential Applications

Hardly accessible mountainous areas. The features of the FMS - portable, highly mobile, and minimal maintenance make it highly usable in mountainous and high elevation areas where permanent weather monitoring instruments cannot be economically maintained. In the northern Philippines where highland agriculture is the way of life of local ethnic communities, the use of the FMS for climate monitoring for decision-support is overwhelming.

Smaller-scale crop simulation studies. When doing crop modeling and yield simulation studies, data inputs must have to be representative of the actual field conditions, otherwise, anomalous simulations can always occur. In Nueva Vizcaya, differences in weather conditions change abruptly due to sudden changes in elevation and slope conditions. It is insufficient and anomalous to use macroscale observations (i.e regional and national meteorological data) due to its wide scope. In this case, it is impossible to capture differences between small areas within a small watershed with highly variable physiographic conditions that vary at the meso- or microscales.

It is imperative that hard data be obtained from the high elevated areas to determine climatic differences, particularly temperature and rainfall amount and patterns. This would require additional instrumentation.

5. Collaborations and Future Directions

Funding from both government and private agencies will be sought. The collaboration that was initiated with the local government units (LGU) in Nueva Vizcaya will be further strengthened by providing trainings and seminars to farmer-stakeholders and extension workers at the local on the application of weather information on their farming activities.

Scientific collaborations shall be strengthened by presenting accomplishments at national and international forums. For the past years since the project was initiated, updates and accomplishments have been presented in national symposia organized by the National Academy of Science and Technology (NAST) of the Philippines and at the GRENE meeting, a group of scientists working in climate change adaptation and mitigation in Monsoon Asia.

As climate is one of the priority areas of the Philippines’ Bureau of Agricultural Research (BAR), an upscaling research proposal to enhance instrumentation is being developed to develop and strengthen collaboration and funding.
Fig. 2. Ten-year (2003-2012) rainfall pattern and amount (mm) in central Nueva Vizcaya, Philippines
Optimizing Water Management of System of Rice Intensification for Climate Change Adaptation Strategy Based on Field Monitored Data

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Summary: Water saving practice is one of the priorities in maintaining the sustainability of rice farming for climate change adaptation strategy. More rice is possibly produced with more efficient water use under system of rice intensification (SRI). In this study, an optimal SRI water management regime in rice production was determined by a genetic algorithm model based on field monitored data. Here, the optimal SRI water management regime is represented as the optimal combination of soil moisture levels in four growth stages. Soil moisture conditions were classified into three levels, i.e., wet (W), medium (M), and dry (D) according to the soil water retention curve. The optimal SRI water management was empirically searched by the genetic algorithm model based on the field monitored data during three cropping seasons. As a result, the optimal combination of soil moisture levels was 0.622 (W), 0.563 (W), 0.522 (M), and 0.350 cm3/cm3 (D) for initial, crop development, mid-season and late season growth stages, respectively. We called this regime as W-W-M-D regime. The wet level in the initial and crop development stages is required to provide enough water for the plant to develop root, stem and tiller in the vegetative phase, and then the medium level is important to avoid spikelet sterility in the mid-season stage. Finally, dry level can be applied in the field to save more water because the minimum water requirement is needed in the late season stage. By the optimal combination, it was estimated that the yield can be increased up to 6.33% and water productivity up to 25.1% with saving water up to 12.7%.

Optimizing water management to find the best combination of wet and dry conditions that maximizes yield and water productivity simultaneously.

In fact, there are many factors to be considered in the irrigation planning model to optimize water management, such as crop water requirement, production function, precipitation, soil water balance, plant growth stage, etc [3]. It is a difficult problem to find the optimal or near optimal solution with traditional optimization methods because of limitations in integrating multiple factors in the model. Thus, genetic algorithm (GA) proposes global optimization search with many remarkable characteristics by searching the entire population instead of moving from one point to the next as the traditional methods [4].

The objective of this study was to combine the information on field monitored data and GA model-based optimization in determining the optimal SRI water management for maximizing yield and water productivity.

Keywords: Climate Change, System of Rice Intensification, Water Management, Soil Moisture, Optimization, Genetic Algorithm

1. Introduction

Recently, the competition of water resource for rice production increased with the increased water requirement for paddy fields as affected by climate change [1]. Water saving technology is one of the priorities in rice research for climate change adaptation strategy in maintaining the sustainability of rice farming. System of rice intensification (SRI) is proposed as an alternative of rice farming with more efficient water use for producing more rice by changing the management of plants, soil, water, and nutrients. In this system, intermittent irrigation is applied in which the field is allowed dry during particular time instead of keeping them continuously flooding, a practice called alternate wetting and drying irrigation [2]. Many experiments have been conducted by comparing continuous flooding as common practice in rice farming and alternate wetting and drying irrigation under SRI. It is clearly observed that alternate wetting and drying irrigation increased water productivity significantly.

However, this regime is vulnerable to water shortage in the field that decreases the yield significantly. Field monitoring is important to prevent water shortage when minimum water is applied in the field. In addition, the field monitored data are required as basic information in determining optimal SRI water management. As climate change adaptation strategy, it is important to consider water use efficiency by increasing water productivity as the output of optimal water management in addition to yield. So far, there is a lack of information studies on optimizing water management to find the best combination of wet and dry conditions that maximizes yield and water productivity simultaneously.

In fact, there are many factors to be considered in the irrigation planning model to optimize water management, such as crop water requirement, production function, precipitation, soil water balance, plant growth stage, etc [3]. It is a difficult problem to find the optimal or near optimal solution with traditional optimization methods because of limitations in integrating multiple factors in the model. Thus, genetic algorithm (GA) proposes global optimization search with many remarkable characteristics by searching the entire population instead of moving from one point to the next as the traditional methods [4].

The objective of this study was to combine the information on field monitored data and GA model-based optimization in determining the optimal SRI water management for maximizing yield and water productivity.

2. Methodology

2.1 Field Monitoring System

A field monitoring system was set up under natural environment in the Nusantara Organic SRI Center (NOSC), in Nagrak, Sukabumi, West Java (6050°42.38”S, 106048’19.96”E, altitude 536 m above sea level) prior to three cropping seasons (Table 1). In NOSC, we prepared four plots with different irrigation regimes. The elements
Table 1. Cultivation period of each cropping season.

<table>
<thead>
<tr>
<th>Season</th>
<th>Planting date</th>
<th>Harvesting date</th>
<th>Rainy/Dry</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>October 14, 2010</td>
<td>February 8, 2011</td>
<td>Rainy</td>
</tr>
<tr>
<td>Second</td>
<td>August 20, 2011</td>
<td>December 15, 2011</td>
<td>Dry - Rainy</td>
</tr>
<tr>
<td>Third</td>
<td>March 22, 2012</td>
<td>July 5, 2012</td>
<td>Rainy - Dry</td>
</tr>
</tbody>
</table>

2.2 Genetic Algorithm (GA) model-based optimization

All of monitored data were used as basic information to find the optimal SRI water management. It was represented by combination of soil moisture levels in four growth stages, i.e., initial, crop development, mid-season, and late season stages. Soil moisture levels were classified into three levels, i.e., wet (W), medium (M), and dry (D) according to the soil water retention curve. The wet level was achieved when pF value was between 0 and 1.6 which was the air entry value for this soil. The medium level was achieved when pF value was between 1.6 and 2.54 which was the field capacity value. When pF values was higher than 2.54, the condition was regarded as the dry level.

Correlation between yield and the average soil moisture in each growth stage was identified firstly before performing optimization process. Here, we used two steps identification to correlate yield and soil moisture levels. Firstly, the correlation between yield and plant growth (i.e., plant height and tillers/hill) by multiple linear regression analysis, and secondly, the correlation between the data from both data loggers, and then to send the data as well as a plant image to the data server through the GSM connection. Users could easily obtain the data by accessing SRI observation website (http://x-ability.jp/FieldRouter/vbox0047/).
the average soil moisture to plant height and tillers/hill by the neural network model.

As a climate change adaptation strategy, optimal SRI water management regime should not only consider yield but also water productivity as the main output. Thus, GA model-based optimization was performed to find optimal combination of soil moisture levels for maximizing yield and water productivity simultaneously. Accordingly, GA model was formulated by the following equations:

The objective function was:

\[
\text{Maximize } F(SM1,SM2,SM3,SM4) \quad (1)
\]

Subject to:

\[
\text{SM} \min < SM1, SM2, SM3, SM4 < \text{SM} \max \quad (2)
\]

where \( SM1, SM2, SM3, SM4 \) are the average soil moisture for initial, crop development, mid-season, and late season stages (cm\(^3/cm^3\)), respectively. \( Y \) is yield (ton/ha). \( WP \) is water productivity (g grain/Kg water). \( d \) and \( e \) are weights for yield and water productivity and their values are 0.6 and 0.4, respectively. \( SM\min \) and \( SM\max \) are the minimum and maximum soil moisture levels from the empirical data (cm\(^3/cm^3\)). Water productivity was calculated using the following equation:

\[
WP = \frac{Y}{\Sigma (I + P)}
\]

where \( I \) is irrigation water (mm) and \( P \) is precipitation (mm).

Since both yield and water productivity have different units, their values were normalized using their maximum and minimum values based on the empirical data. The GA model works to find optimal values of \( SM1, SM2, SM3, SM4 \) in maximizing the objective function in Eq. (1).

3. Results and Discussion

3.1 Effect of Soil Moisture Combinations on Yield

During three cropping seasons, there were 12 different irrigation regimes. Effects of soil moisture combination on yield were presented in Fig. 2. Here, we used the linear correlation between average soil moisture over the growth stages and yield.

In the initial and crop development stages, soil moisture had positive correlations to yield with \( R^2 \) of higher than 0.6. This result revealed that at higher soil moisture levels, more yield was produced. On the contrary, soil moisture had negative correlations to yield in the mid-season and late season stages. In these stages, the maximum yield was obtained when the soil moisture level was higher than the field capacity border. This correlation was important as information to find the optimal soil moisture combination in maximizing yield.

3.2 Optimal SRI water management regime

Table 2 shows the optimal soil moisture level in each growth stage obtained by the GA model. Four irrigation regimes with the combinations of soil moisture levels from the field measurements are also represented in the table during the third cropping season for the comparison.

The optimal combination of soil moisture levels in the growth stages was 0.622 (wet), 0.563 (wet), 0.522 (medium), and 0.350 cm\(^3/cm^3\) (dry) for SM1, SM2, SM3 and SM4, respectively. We called this regime as W-W-M-D regime. The wet level is required in the initial and crop development stages because the plants need more water for initial growth especially vegetative phase in developing root, stem, leaf and tiller. However, deep standing water should be avoided because rice plants cannot grow well with limited oxygen concentration under flooding conditions [6]. In the mid-season stage, the medium level is required when plants are focusing on their generative phase (flowering and panicle development). In this stage, an aerobic soil condition is required to avoid spikelet sterility particularly around flowering time [7], thus the soil moisture level can be reduced into the medium level. Finally, in the late season stage, the dry level could be applied in the field to save more water because all plant organs are perfectly developed. In this stage, minimum water input could be supplied in the field because minimum plant water requirement is needed [8]. By this scenario, it was estimated that the yield can be increased up to 6.33% and water productivity up to 25.1% with water saving up to 12.7%.

4. Conclusions

In this study, the optimal SRI water management for climate change adaptation strategy was determined by combining the information of field monitored data and GA model-based optimization in maximizing yield and water productivity simultaneously. As a result, the optimal combination of soil moisture levels was 0.622 (W), 0.563 (W), 0.522 (M), and 0.350 cm\(^3/cm^3\) (D) for initial, crop development, mid-season and late season growth stages, respectively. We called this regime as W-W-M-D regime. The wet level in the initial and crop development stages is required to provide enough water for the plant to develop root, stem and tiller in the vegetative phase, and then the medium level is important to avoid spikelet sterility in the mid-season stage. Finally, dry level can be applied in the field to save more water because the minimum water requirement is needed in the late season stage. By the optimal combination, it was estimated that the yield can be increased up to 6.33% and water productivity up to 25.1% with saving water up to 12.7%.

Acknowledgement

We are grateful to Ministry of Education, Culture, Sports, Science and Technology (MEXT) Japan for their support through Green Network of Excellence (GRENE) project for this study.
Fig. 2 Linear correlation between soil moisture and yield in each growth stage.

Table 2. Optimal soil moisture level in each growth stage and its comparison to the irrigation regimes in the third cropping season.

<table>
<thead>
<tr>
<th>Components</th>
<th>Irrigation regimes from field experiment</th>
<th>GA model</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plot 1</td>
<td>Plot 2</td>
</tr>
<tr>
<td>Soil moisture (cm3/cm3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial (SM1)</td>
<td>0.622</td>
<td>0.602</td>
</tr>
<tr>
<td>Crop development (SM2)</td>
<td>0.592</td>
<td>0.585</td>
</tr>
<tr>
<td>Mid-season (SM3)</td>
<td>0.522</td>
<td>0.488</td>
</tr>
<tr>
<td>Late season (SM4)</td>
<td>0.505</td>
<td>0.401</td>
</tr>
<tr>
<td>Yield (ton/ha)</td>
<td>10.0</td>
<td>9.38</td>
</tr>
<tr>
<td>Total irrigation (mm)</td>
<td>343</td>
<td>295</td>
</tr>
<tr>
<td>Total precipitation (mm)</td>
<td>551</td>
<td>551</td>
</tr>
<tr>
<td>Water productivity (g grain/kg water)</td>
<td>1.12</td>
<td>1.11</td>
</tr>
<tr>
<td>Water saving (%)</td>
<td>-</td>
<td>13.9%</td>
</tr>
</tbody>
</table>
References


Soil Moisture Monitoring Using Field Monitoring System (FMS) and Analysis of Rainfall Data for Tomato Cropping Calendar under Batac City, Ilocos Norte, Philippines Condition

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Summary: A demonstration study on soil moisture monitoring using a Field Monitoring System (FMS) was conducted in a tomato field in 16N, Quiling Norte, Batac City, Philippines. The FMS used in this study consisted of an intelligent sensor node which is capable of automatically measuring rainfall, relative humidity, solar radiation, soil moisture/temperature/electrical conductivity and wind speed. The system, however, was not equipped with field router. Dynamic changes in soil moisture/temperature/EC was particularly measured and monitored. Based on the findings of the demonstration experiment, the system was effective, reliable, and efficient in monitoring the available moisture in the soil. Irrigation commences when 56-60% of Readily Available Moisture (RAM) has been depleted. Irrigation was done every 11 days at a depth of 50 mm to a field capacity of 24%. Meanwhile, tomato may be best planted on May 11 to May 19 during the rainy season (upland condition) and on the first week of November during the dry season. Better and more detailed understanding of the changes in local environmental and meteorological conditions in 16N Batac City, Ilocos Norte is possible using the FMS data for the next several years. With the noticeable manifestations of climate change, probable modification of the formulated cropping calendar may be done as an adaptation measure in tomato production.

Keywords: Field Monitoring System, Readily Available Moisture, Irrigation, Sensors, Cropping Calendar, Climate Change

1. Introduction

Tomato is a significant cash crop which has been recognized for its nutritional value, fast growth which may permit several crops each year, and its importance for food and income generation to those with little land available for food production

Tomato may react strongly to moisture conditions of the soil. Too little as well as too much soil water adversely affect the yield especially the growing period and at maturity. The present practice of farmers in the locality in terms of the amount of irrigation water being applied to the crop under study is based on “enough already” or irrational estimates. With this, farmer’s maybe applying too much or too little of irrigation water which may adversely affect the yield performance of the crop [3].

Keeping the right amount of moisture needed by the crop during its entire growth duration may bring optimum yield as well as sustainable farming system through water conservation. This may be done using a field monitoring system (FMS).

Tomato is a dry season major rice-based crop commonly grown in Ilocos Norte, Philippines. Sufficient moisture must be available during critical growth stages particularly during transplanting and flowering. On the average, tomato requires 35 mm of water per week for good growth and development. Hence, determination of potential planting date via rainfall analysis is critical for optimum yield and water savings.

2. Objective of the Study

In general, the study aims to demonstrate soil moisture monitoring in a tomato field and recommend a scientific cropping calendar for tomato. Its specific objectives are:

a) To monitor soil moisture in a tomato field to precisely determine when to irrigate and how much to irrigate using FMS; and

b) To be able to determine the start of rains, maximum dry run, and end of rains for the 23 year rainfall record (1990-2012) at MMSU Agromet Station as basis for tomato cropping calendar.

3. Review of Related Literature and Studies

Tomato (Lycopersicum esculentum) is a bushy or vine rapidly growing crop with a growing period of 90 to 150 days. It is one leading vegetable in the Philippines based on the value of production. Its fruit contains significant amount of Vitamin A and C, which can be processed into juice, paste and sauce or sold as fresh tomato for salad and pickle ingredient. This vegetable crop commands high price and is one of the most profitable crops grown in Ilocos during the rainy months or early part of dry season when supply is scarce [1].

Tomato is a daylength neutral plant. Optimum mean daily temperature for growth is 18 to 25°C with night temperatures between 10 and 20°C. Temperatures above 25°C, when accompanied by high humidity and strong wind, result in reduced yield. Night temperatures above 20°C accompanied by high humidity and low sunshine lead
to excessive vegetative growth and poor fruit production. High humidity leads to a greater incidence of pests and diseases and fruit rotting. Dry climates are therefore preferred for tomato production.

Tomato can be grown on a wide range of soils but a well-drained, light loam soil with pH of 5 to 7 is preferred. Waterlogging increases the incidence of diseases such as bacterial wilt. The crop is moderately sensitive to soil salinity. Yield decrease at various ECe values is: 0% at ECe 2.5 mmhos/cm, 10% at 3.5, 25% at 5.0, 50% at 7.6 and 100% at ECe 12.5 mmhos/cm. The most sensitive period to salinity is during germination and early plant development, and necessary leaching of salts is therefore frequently practised during pre-irrigation or by over-watering during the initial irrigation application [4].

Irrigation Requirement of Tomato

A study on the effect of different irrigation schedules on the growth and yield performance of tomato under MMSU condition was conducted in 2007. Allowable depletion of 51-55% of the Readily Available Moisture (RAM) was found suitable for optimum yield. Further, irrigation of the crop was done every 11 days. The recommended quantity of water to be applied per irrigation was 48.7mm. The crop water requirement of the crop throughout its growing period was found to be 667.75 mm [3].

In another study, it was revealed that a slightly higher range of allowable depletion in terms of allowable soil moisture depletion was suitable for optimum yield. Economically, a 56-60% of RAM is the most suitable [2].

4. Methodology

Locale and Description of the Study Area

The demonstration study was carried out under natural paddy-tomato-corn-finger pepper field. A 600 m² Farmers’ field in 16N Quiling Norte, Batac City, Ilocos Norte was selected for experimentation. The source of irrigation water was from a shallow tubewell which was delivered to the field via PVC pipes. The average monthly precipitation, solar radiation, air temperature, wind speed, and relative humidity were 3.0 mm, 69.09 W/m², 25.37°C, 0.52 m/s, and 88.65%, respectively during the study period.

Ilocos Norte, Batac City in particular, has two distinct seasons: rainy and dry seasons. The rainy season or wet season occurs from the later part of May to September. The dry season is from October to early part of May. Mean total rainfall from October to May (dry season) ranged from 1.92mm to 169.45mm.

Land Preparation

The experimental area was plowed and harrowed twice in order to pulverize the soil and make the soil surface more uniform and level prior to planting. Soil samples were collected at the experimental area before the establishment of tomato crop. Spacing between plants was 35 cm and spacing between rows was 90 cm.

Irrigation

Furrow irrigation method using irrigation pipes was used in this study. The equivalent depth of irrigation for every treatment was computed by Eq. (1):

\[
d = \frac{(FC - AWD)(A_s)(dr)}{100}
\]

Where:
- \(d\) = equivalent depth of water to be applied, mm or cm
- \(FC\) = field capacity, %
- \(AWD\) = allowable moisture depletion
- Pre-determined value = 56-60% of Readily Available Moisture (RAM)
- \(RAM = 75\%\) of Available Moisture (AM)
- \(As\) = apparent specific gravity
- \(dr\) = effective depth of root zone, mm or cm

The available moisture of the soil is computed Eq. (2):

\[
AM = FC - PWP
\]

Where:
- \(AM\) = Available moisture, %
- \(FC\) = Field capacity, %
- \(PWP\) = Permanent wilting point, %

The permanent wilting point was determined using sunflower plants. The moisture content of the soil was determined when the test plants showed signs of permanent wilting and was considered its PWP.

Moisture Content Determination

The daily content of the soil was monitored using the calibrated soils sensor of the Field Monitoring System. Data was periodically and manually downloaded. Irrigation water was then applied when the pre-determined allowable depletion was reached.

Other cultural management such as fertilizer application, seeding, transplanting, weeding, pesticide application, harvesting among others were based on the package of technology for tomato.

Field Monitoring System Set-up

A Vantage Pro2 Weather Station- Field Server with 5-port Em50 data logger connection was installed in the study site (Fig. 1). In the absence of field router, data such as solar radiation, air temperature, humidity, wind direction, wind speed, precipitation, soil moisture content, soil temperature, and electrical conductivity of soil were downloaded manually. The downloaded data were then processed, analyzed, and interpreted.

Soil moisture sensors (5TE: soil moisture,
temperature, EC), developed by Decagon Devices, Inc., USA, were installed at 15 cm below the soil surface which were connected to the 5-port Em50 Data Logger.

Rainfall Analysis

Twenty three (23) years of rainfall data (1990-2010) taken from Mariano Marcos State University (MMSU) Agrometeorological Station were analyzed using the INSTAT program. INSTAT is a statistical package having special facilities for handling and processing climatic data (particularly rainfall) providing useful statistics necessary for precision farming.

Primary focus of the analysis was on the determination of start of rains, maximum dry run and End of rains (end of season) on a daily basis per year. These were summarized using the useful statistics like minimum, maximum, mean, median, and standard deviation. Further analysis was done using percentile points at 10, 20 50, 80 and 90 percentage points.

Limitation of the Study

The study was limited only to the demonstration of the functionality of the Field monitoring system. Hence, yield data and other more detailed agronomic characterization were not gathered. Gathering of yield data and production results of the trials were scheduled for the Phase 2 of the study when a Field Router is already available.

Moreover, the 8-month rainfall data and other agrometeorological data recorded by the FMS in this study are not yet adequate for reliable weather forecasting analysis particularly rainfall analysis.

5. Results and Discussion

Soil Moisture Monitoring

The soil moisture sensor of the FMS was laid out at a depth of 15 cm in a loam field. The field capacity and allowable depletion of readily available moisture was calibrated for the FMS using gravimetric method. The field capacity and wilting point was found to be 24% (0.412 m3/m3) and 10% (0.253 m3/m3), respectively. The allowable moisture depletion of 56-60% of RAM was translated into volumetric water content. An hourly data recording was set at the ECH2O software of the FMS which was manually monitored and downloaded. The FMS was found effective in precisely monitoring the periodic depletion of soil moisture. Results of the study revealed that the actual irrigation interval is 11 days with 50mm depth of application.

Start of the Rains

Start of rains may be defined in different ways for different purposes. A definition may be based solely on rainfall amount. In this study, two definitions were considered:

(i) The first occasion after first April or May) that there is more than 20mm either on a single day, or within 2 days. 15th April was considered as a third alternative earliest date. Code: First 92 106 122 day numbers.

(ii) The first occasion after the same dates in (i) that the (running) 10 day total is greater than half the evapotranspiration assumed as 5mm/day.

As reflected in Table 1, the mean start of rains ranged from 133-140 days of year (May 12 – May 19).
This implies that in Batac City, the start of rainy season is May. The 80 percent is the value that is exceeded 1 year in 5 years \((1/0.2) = 5\). At that point, the mean start of rains ranged from 132-140 days of year (May 11 – May 19).

In tropical countries tomatoes do not grow well during the rainy season. They are often affected by insects and diseases that thrive during the rainy months. However, tomato hybrid varieties that are resistant to rainy condition may be planted. To save irrigation cost, the tomato seedlings maybe planted on the onset of rainy season (May) in an upland condition. The plants will be ready for harvest before the start of typhoon season which is usually August to September.

### Maximum Dry Run

Spell lengths through each year was examined with the SPELL command of the INSTAT. Dry days were days defined as less than 0.85mm of rainfall (This threshold value of rainfall was considered but other values can be used).

Based on the results, the mean maximum dry run for the 23 year record in May, June, and July were 22, 9.22 and 6.70 days respectively. The values are actually dry spells that have been considered to continue over the end of the month (i.e. a dry spell in April when it continues in May will be recorded and covered in May). Maximum dry runs at 80-percentage point chance of dry spells in those same months were 34, 12 and 11 days.

### End Season/Rains

The WATer balance command of the INSTAT program was used to determine the end of rains. The end of the rains was defined as the first occasion after 1st September that the water balance dropped to zero. A 5mm evaporation was value was based on the dry season evapotranspiration in Batac City, Ilocos Norte which was computed using the FAO-Penman Monteith Method. The maximum soil capacity was taken as 100mm.

Table 1 reveals that the mean end of the season was approximately 297 day of the year (October 23) which was based on rainfall and the water storage. In the daily water balance analysis, water starts to diminish in October and zeroing in January, February and March. The soil water reservoir is rain recharge in May.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Estimated mean value</th>
<th>Estimated value (80% Probability)</th>
<th>Recommended transplanting date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of rains</td>
<td>133-140 day of year</td>
<td>132-140 day of year</td>
<td>May 11 – May 19</td>
</tr>
<tr>
<td></td>
<td>or May 12 – May 19</td>
<td>or May 11 – May 19</td>
<td>(rainy season)</td>
</tr>
<tr>
<td>Maximum dry run</td>
<td>May = 22 days</td>
<td>May = 34 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td>June = 9.22 days</td>
<td>June = 12 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td>July = 6.70days</td>
<td>July = 11days</td>
<td></td>
</tr>
<tr>
<td>End of rains</td>
<td>297 day of the year</td>
<td>310 day of the year</td>
<td>1st week of November</td>
</tr>
<tr>
<td></td>
<td>October 23</td>
<td>or November 5</td>
<td>(dry season)</td>
</tr>
</tbody>
</table>

At 80 percentage point, the end of rains was 310 day of the year (November 5).

In tomato production, frequent rains are undesirable because they make cultural operations difficult. Excessive rainfall drowns the plants and leaches the nutrients especially on light soils.

Considering the above conditions, transplanting date of tomato on October 23 onwards is justified. Irrigation is scheduled based on the irrigation interval of 11 days. To be beneficial, the irrigation water must reach the depth of the main concentration of roots. In the Philippines greatest root concentration occurs at the depth of about 15 to 20 cm with effective root zone of 50-60 cm.

### Climate Change and Adaptation Measure

Better and more detailed understanding of the changes in local environmental and meteorological conditions in 16N Batac City, Ilocos Norte is possible using the FMS data for next several years. With the noticeable manifestations of climate change, probable modification of the formulated cropping calendar may be done as an adaptation measure in tomato production.

### References


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Table 1. Start of rains, maximum dry run, end of rains, and recommended cropping calendar for tomato in Batac City, Ilocos Norte, Philippines.
Vulnerability Analysis and Climate Change Mitigation Strategies of the Aringay River Watershed in the Province of La Union, Philippines

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Summary: This study assessed the vulnerability analysis of the Aringay River Watershed in La Union, Philippines along socio-economic profile, perception analysis of the extent of vulnerability and capabilities and constraints as basis in the formulation of a one-year operational plan/ climate change mitigation strategies. The descriptive method of research was used with 246 respondents. Findings showed moderate awareness of the respondents on the effect of natural and anthropogenic or man-made causes of vulnerability and a significant relationship was established along natural and anthropogenic or man-made causes as indicated by r-value of 0.763. There were identified constraints that contributed to the causes of vulnerability of the Aringay Watershed which was utilized in the formulation of the one-year operational plan/ climate change mitigation strategies.

Keywords: Vulnerability, Watershed, Anthropogenic

1. Introduction

A watershed is a land area drained by a stream or fixed body of water and its tributaries having a common outlet for surface run-off (PD 705). It usually ranges from one to 100,000 hectare area. More than 100,000 hectares, the area is now considered as river basin. Watersheds have been very important in many aspects like being the source of water for domestic, irrigation and hydropower. It also forms part of hydrological cycles, ecology and determining regions’ boundaries.

The Philippines is one big watershed with a total land area of 30,000,000 hectares. The area is composed of certified alienable and disposable lands and public forests. During the May 2009 North Luzon Inter-Regional Summit on Water Resources and Environment, 77 river basins/ watersheds in the North Luzon Growth Area, composed of Regions 1, 2 and CAR, were cited.

The Aringay River Watershed is one of the five major river watersheds in the Province of La Union with an approximate land area of 22,566.20 hectares or about 53.70 percent of the total river basin area. It covers 64 barangays from six municipalities, namely: Aringay, Caba, Naguilian, Pugo, Rosario and Tubao. The Aringay River Watershed used to be rich in natural resources. Due to continued exploitation and indiscriminate cultivation, the watershed lost its ecological significance such as deforestation and removal of natural vegetation.

Statement of the Problem

Generally, this study assessed the vulnerability analysis of the Aringay River Watershed in La Union, Philippines, as basis in the formulation of a one-year operational plan. Specifically, it sought answers to the following questions: 1) what is the socio economic profile of the respondents as to age, gender, religion, marital status, highest educational attainment, monthly income, and years in service?; 2) what is the extent of the respondents’ awareness on the vulnerability of Aringay River Watershed in terms of natural causes and anthropogenic or man-made causes?; 3) are there significant relationship between the extents of awareness on the vulnerability along natural and anthropogenic causes in terms of: a) fire; b) landslide; c) illegal logging, deforestation and/ or biodiversity loss; and d) resource degradation?; 4) what capabilities and constraints contributed to the extent off awareness of respondents on the causes of vulnerability?; and 5) what validated operational plan/ mitigation strategies can be formulated?

2. Related Literature

Vulnerability refers to conditions which define how elements exposed to risks are affected by hazards. It implies equally well to physical entities (people, ecosystems, coastlines, etc.) and to abstract concepts (social systems, economic systems, countries). In the past years, the eco-friendly vulnerability has shown a significant change. However, the driving forces for the change are mainly related to the impact of socio-economic factors, resulting to increasing pressure of human activities on land, which lead to rapid change of land-use.

The current environmental problems in the Philippines include uncontrolled deforestation, increased soil erosion, air and water pollution in cities, and siltation of coastal mangrove swamps which are vital fish breeding grounds. Apparently, forest denudation influences all the other problems mentioned.

Watershed degradation in the Philippines is attributed to a wide range of physical and socio-economic factors that are often complex and to a substantial degree
is localized in nature. These factors are described as: a) monsoonal climate pattern; b) extreme climate events; c) frequent floods; d) rugged terrain coupled with geologic instability associated with seismic and volcanic activity; and e) soils which are strongly acidic, with low natural fertility, strong leaching associated with high rainfall, and rapid decomposition of organic matter. Furthermore, [9] mentioned a number of key causes of watershed erosions, which include: a) improper human activity; b) increasing population; c) poverty and economic disadvantages; d) inadequate institutional support services; e) inappropriate land use restrictions; and f) insecure land user rights.

Environmental issues and problems identified during the characterization of the Aringay River Watershed on forest or upland areas include the fast deforestation or removal of natural vegetation as a result of kaingin and charcoal making by forest dependents and timber poaching or illegal cutting especially in the timberlands of the Municipality of Pugo and Tubao [5]. These major problems are being triggered by other root problems felt in the area which include rapid population increase both in the uplands and lowlands, aggravated poverty and lack of alternative livelihood. These problems, if left unattended, will lead to soil erosion, siltation of creeks and rivers, air and water pollution, and adverse effect to air temperature and to the lives of freshwater and marine organisms.

3. Methodology

Research Design and Data Collection

The study made use of descriptive method of research. The survey instruments were adopted from one of the tools used by the Department of Environment and Natural Resources - Forest Management Service on Vulnerability Assessment for the Aringay River Watershed. The municipalities concerned are Aringay, Caba, Naguilian, Pugo, Rosario and Tubao. The respondents (246) were composed of barangay captains, all other factors were moderate. This supported the findings of [8] that fire is one of the specific causes of forest degradation in the communities in the Cordillera. Fire is prevalent during the summer months, caused by accidents, the deliberate burning of wildlife habitat for hunters in the forest or burning of weeds on the farm.

Data Analysis

The socio-economic characteristics of the respondents were determined using frequency counts and percentages. The weighted means and Likert Scales were used with their corresponding statistical range and descriptive equivalents along the extent of awareness. The significant relationship made use of the Pearson-r method. Capabilities and constraints were determined by setting correlation net of range 3.40-5.00 for capabilities and 1.00-3.39 for constraints. The extent of awareness of vulnerability from fire and landslide due to natural causes; also from illegal logging, deforestation or biodiversity loss and resources degradation due to anthropogenic or man-made causes, and the level of validity of the operational plan were identified with the corresponding point values, statistical range and descriptive equivalents. To facilitate computations, Microsoft Excel (MS Excel) and Statistical Package for Social Science (SPSS) were used.

4. Results and Discussion

Socio-Economic Profile

Majority of the respondents were male (65.43%), married (86.83%), ages 50 and above (51.85%). Most of them are Roman Catholic (79.84%), with High School level as the highest educational attainment (45.68%). There were 86.42% of the total respondents who had a monthly income of 10,000 and below while the highest percentage for work experience (55.14%) is along the 10 years and below bracket.

Awareness on the Effects of Natural and Man-Made or Anthropogenic Causes of Vulnerability

Fire. The over-all extent of awareness of fire as a cause of vulnerability along the Aringay River Watershed was moderate. Except for technological factors which showed a low extent of awareness particularly of the barangay captains, all other factors were moderate. This supported the findings of [8] that fire is one of the specific causes of forest degradation in the communities in the Cordillera. Fire is prevalent during the summer months, caused by accidents, the deliberate burning of wildlife habitat for hunters in the forest or burning of weeds on the farm.

Landslide. There was a moderate extent of awareness of landslide as a cause of vulnerability within the Aringay River Watershed. However, the biophysical factors showed high extent of awareness with the occurrence of landslides in the area. Results confirmed that people living within the watershed area have witnessed the occurrence of landslides. Technological factors showed a low extent of awareness. This is supported by the result of study of Halim, et al., (2007) which states that any soil conservation practices due to lack of awareness on soil erosion result to severe erosion hazard coupled with high silt content, high rainfall and steep slope.

Illegal Logging, Deforestation and/or Biodiversity Loss as Man-Made cause of Vulnerability. Forest is used mainly for fuel wood for the Cordillera rainy season where temperatures can become very low [9]. Timber for construction is extracted from watershed and this is generally used to build houses. According to [8], excessive logging activities or timber harvesting, shifting cultivation and conversion of forest areas to other land uses were a common practice in watersheds. Illegal timber cutting is one of the specific causes of forest degradation in the communities in Cordillera. This supports the result of the study that respondents showed moderate extent of awareness on illegal logging, deforestation and/or
biodiversity loss as a cause of vulnerability within the Aringay River Watershed. Despite the knowledge on local policies on the protection of communal forest areas, communities still rely principally on forest resources, contributing to further forest denudation.

Resource Degradation. The extent of awareness of resource degradation as a cause of vulnerability within the Aringay River Watershed registered an average moderate rating. The policy makers had the highest extent of awareness. However, the peoples’ organization members and the barangay captains, particularly, had low extent of awareness on technological factors. This indicates that respondents have little knowledge on mitigation and prevention of resource degradation.

Relationship between the Extent of Awareness on the Vulnerability of Natural and Man-made Causes

Table 1 reveals that there is significant relationship between the extents of awareness on vulnerability along the natural and man-made or anthropogenic causes as indicated by r-value of 0.763. This means that the higher the cause of vulnerability of natural and man-made, the higher the extent of awareness within the Aringay River Watershed. Specifically, the data confirmed that there were significant relationships between awareness on the causes of natural and man-made or anthropogenic factors to: a) fire and illegal logging, deforestation and/or biodiversity loss with r-value of 0.644; b) fire and resource degradation with r-value of 0.551; c) landslide with illegal logging, deforestation and/or biodiversity loss with r-value of 0.666; and d) landslide and resource degradation with r-value of 0.610.

Capabilities and Constraints Analysis on the Extent of Effects of Vulnerability of Natural and Man-made or Anthropogenic Causes

There were three indicators of fire, three indicators of landslide, two indicators of illegal logging, deforestation and/or biodiversity loss and two indicators of resource degradation identified as constraints while there are 20 indicators of fire, 10 indicators of landslide, 18 indicators of illegal logging, deforestation and/or biodiversity loss and 13 indicators of resource degradation identified as capabilities within the Aringay River Watershed.

One-year Operational Plan/ Mitigation Strategies for the Aringay River Watershed

The one-year operational plan/ mitigation strategies for the Aringay River Watershed were formulated based on identified constraints and capabilities. There were 14 watershed technical experts and planning officers who validated the one-year operational plan/ mitigation strategies for the Aringay River Watershed. The level of validity was fully acceptable, partially functional, and partially attainable and the overall validity was fully valid.

5. Conclusion

Findings of the study revealed that the respondents were aware on the vulnerability of Aringay River Watershed in terms of fire, landslide, illegal logging, deforestation and biodiversity loss, and resource degradation. The natural causes of vulnerability are significantly related to the anthropogenic or man-made causes of vulnerability. However, there are more constraints than capabilities in the level of effects of the factors of the natural and anthropogenic or man-made causes of vulnerability identified in the Aringay River Watershed. In terms of acceptability, functionality and attainability, the operational plan/ mitigation strategies for the Aringay River Watershed for Calendar Year 2012 is fully valid.

Recommendations

Based on the conclusions drawn, the following are recommended:

1. Specific programs, projects and activities on mitigation and protection should be adopted and implemented to prevent the occurrences of natural and anthropogenic causes within the Aringay River Watershed;
2. A comprehensive assessment should be taken to determine symbiotic relationship of natural and anthropogenic or man-made causes and its effects to the Aringay River Watershed;
3. Specific programs, projects and activities should be identified for implementation in order to mitigate and protect the Aringay River Watershed;

<table>
<thead>
<tr>
<th>Extent of awareness on the causes of vulnerability</th>
<th>Illegal logging, deforestation and/or biodiversity loss</th>
<th>Resource degradation</th>
<th>Man-made or Anthropogenic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire</td>
<td>0.644**</td>
<td>0.551**</td>
<td>0.678**</td>
</tr>
<tr>
<td>Landslide</td>
<td>0.666**</td>
<td>0.610**</td>
<td>0.723**</td>
</tr>
<tr>
<td>Natural</td>
<td>0.713**</td>
<td>0.623**</td>
<td>0.763**</td>
</tr>
</tbody>
</table>

Legend: ** - correlation is significant at the 0.01 level (2-tailed)
4. A more detailed study should be conducted further to include the Municipalities of Agoo, Santo Tomas and Bauang, and the upstream tributaries of the Aringay River Watershed in the Cordillera Region;

5. The formulated one-year Aringay River Watershed Operational Plan is humbly offered for consideration and adoption; and

6. Other researchers are encouraged to initiate and conduct sustainable development research investigations to broaden the understanding and concern for environmental protection and other issues.

References


Recycling of Abattoir Wastes (Cattle Rumen Contents) for Animal Feeding: A Localized Alternative to Climate Change Mitigation

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**Keywords:** Cattle Rumen Contents, CRC, Climate Change, Ingesta, Slaughter Wastes

1. Introduction

Climate change is a global phenomenon and a serious threat requiring urgent response from all sectors of the society. Rural poor communities are among the most climate-sensitive economic sectors of the society and depend greatly for their survival on agriculture and livestock production.

Cattle rumen contents (CRC) which are considered as abattoir wastes are the partially hydrolyzed ingesta discarded at the time of slaughter. It entirely includes those contents from the rumen. The total capacity of cattle stomach is 66.5 gallons [3] with the average capacities of the different compartments of 53.4 gallons for the rumen, 2.0 gallons for the reticulum, 5.0 gallons for the omasum, and 6.1 gallons for the abomasums. Considering these great amounts, a large volume of CRC are produced and improperly disposed as abattoir wastes. Consequently creates pollution which imposes health and environmental problems.

Such problems could be reduced when these wastes will be utilized for livestock and poultry feeding (Fig. 1). Therefore, this study was conducted to generate benchmark information on the use of CRC in pig diets. Furthermore, it was also done to determine the digestibility, nutritive, feeding and profitability values of CRC as component for

![Process flow on the use of CRC in pig diets (CRC collection, drying, milling and feeding).](image-url)
pig feeding. Data gathered included percent recovery, proximate analysis, digestion trial, feeding experiment, dressing percentage, cost of feed per unit gain in weight and return above feed cost. The feeding trials were conducted for 30-day duration for the starter stage; 60 days for the grower stage; and 26 days for the finisher stage.

2. Results and Discussion

2.1 Percent Recovery of Rumen Contents

Table 1 shows the percent recovery of rumen contents from ten sample slaughtered cattle. Variation in the approximate body weight was observed and ranged from 175.0 to 400.0 kg with an average 287.5 kg. Fresh weight of rumen contents ranged from 14.0 to 30 kg with an average of 22.6 kg. On the other hand, dry weight of rumen contents ranged from 2.5 to 8.5 kg. Rumen content recovery ranged from 17.85 to 28.33%. Data shows that heavier body weight would give a heavier fresh and dry weight, and a higher percent recovery of rumen contents.

2.2 Nutritive value of CRC

The proximate analysis of CRC is presented in Table 2. Laboratory analysis revealed a low gross energy value of 0.72 kcal/kg that translated to low metabolizable energy (ME) of 1,936.6 kcal/kg. High nitrogen free extract (NFE) level of 53.99% in CRC makes it a good source of soluble carbohydrates for pig. The crude protein (CP) content of 15.41% was higher than that of rice bran (D1). It is also possible that CRC contained high levels of microbial proteins from the rumen micro-flora and flora. Considerable amounts of lysine and methionine (0.64 and 0.18%, respectively) were also detected. This information proves that CRC can be a good source of nutrients for pig feeding.

2.3 Digestibility of CRC

The result of the digestion trial is presented in Table 3. Data revealed that fats or ether extract (EE) had the highest digestion coefficient of 75.20% (Table 3). Crude protein (CP) ranked second with a digestion coefficient of 65.20%. Microbial proteins found in CRC could be the reason for this high digestibility. Microbial protein from bacteria or protozoa has a biological value (BV) of about 0.80 [5]. Bacterial protein however, has a lower BV of 0.74 compared to 0.91 for protozoan protein. This coincides with the report of [4] that microbial proteins have high digestion coefficients.

### Table 1. Rumen contents recovered from ten slaughtered cattle.

<table>
<thead>
<tr>
<th>Sample slaughtered cattle</th>
<th>Approximate body weight (kg)</th>
<th>Fresh weight of rumen contents (kg)</th>
<th>Dry weight of rumen contents (kg)</th>
<th>Rumen contents recovered (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>250.0</td>
<td>20.0</td>
<td>5.00</td>
<td>25.00</td>
</tr>
<tr>
<td>2</td>
<td>200.0</td>
<td>17.0</td>
<td>4.00</td>
<td>23.52</td>
</tr>
<tr>
<td>3</td>
<td>300.0</td>
<td>25.0</td>
<td>7.00</td>
<td>28.00</td>
</tr>
<tr>
<td>4</td>
<td>225.0</td>
<td>18.0</td>
<td>4.25</td>
<td>23.61</td>
</tr>
<tr>
<td>5</td>
<td>275.0</td>
<td>22.0</td>
<td>4.50</td>
<td>20.45</td>
</tr>
<tr>
<td>6</td>
<td>175.0</td>
<td>14.0</td>
<td>2.50</td>
<td>17.85</td>
</tr>
<tr>
<td>7</td>
<td>325.0</td>
<td>26.0</td>
<td>7.25</td>
<td>27.88</td>
</tr>
<tr>
<td>8</td>
<td>350.0</td>
<td>27.0</td>
<td>7.50</td>
<td>27.77</td>
</tr>
<tr>
<td>9</td>
<td>375.0</td>
<td>27.0</td>
<td>7.50</td>
<td>27.77</td>
</tr>
<tr>
<td>10</td>
<td>400.0</td>
<td>30.0</td>
<td>8.50</td>
<td>28.33</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,875.0</strong></td>
<td><strong>226.0</strong></td>
<td><strong>58.00</strong></td>
<td><strong>25.02</strong></td>
</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>287.5</strong></td>
<td><strong>22.6</strong></td>
<td><strong>5.80</strong></td>
<td><strong>25.02</strong></td>
</tr>
</tbody>
</table>

*Proximate analysis was done at the Technology Research and Development Center, Adamson University, San Marcelino, Ermita, Manila, Philippines*
The fairly low digestion coefficient of NFE (46.57%) could be attributed to arabinose, mannose and xylose contents of roughages. Cattle rumen contents are basically composed of roughages and it is expected to be high in these forms of carbohydrates. Wilson (1962) reported that these carbohydrates are poorly absorbed; the reason why high amounts of these carbohydrates are present in the manure contributing to higher fecal NFE contents.

Crude fiber had a fair digestion coefficient of 38.62 (Table 3).

2.4 Feeding Trial

CRC diets have nutritive and feeding values that were statistically comparable with the zero percent CRC and commercial pig diets (Table 4). The statistically similar final weight, gain-in-body weight, daily gain in weight and feed consumption supports this conclusion. Although pigs in the control diet were more efficient feed converters and protein users with significantly better FCR and PER, the higher return above feed cost (RAFC) and lower cost of feed per unit gain in weight (CFG) of pigs in the CRC diets were comparable to that of pigs in the 0% CRC diet but much cheaper than that of pigs in the commercial feed. The dressing percentage of pigs given diets with CRC was comparable to those pigs given commercial feeds (Table 5). The lower CFG of pigs in the former diet however, suggests that higher yields are attainable at lower cost if pigs were fed with diets containing CRC. Thinner and more desirable backfat of pigs in the CRC diets indicate a better quality carcass. This suggests that CRC can be beneficially used in pig diets for better quality carcasses and therefore increase its acceptability to consumers.

2.5 Return above Feed Cost (RAFC)

Lower returns were realized from finished pigs given commercial feeds due to high feed cost (Table 6). Although pigs in this diet registered better FCR than those finished pigs given CRC in the diets, this did not result in higher RAFC due to high cost of the diet. The higher RAFC values of the treated diets were attributed to the low costs of CRC thus, making the diet cheaper on a unit basis.

2.6 Cost of feed per unit gain in weight (CFG)

Pigs fed with diets containing CRC incurred the least feed cost per kilogram gain in weight compared to pigs given commercial feeds and no CRC in the diet (Table 7). The significantly better CFG incurred by the

<table>
<thead>
<tr>
<th>Treatments</th>
<th>IW</th>
<th>FW</th>
<th>ADG</th>
<th>AGW</th>
<th>FC</th>
<th>FCR</th>
<th>PER</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 0% CRC</td>
<td>79.67</td>
<td>98.57</td>
<td>0.74</td>
<td>19.35</td>
<td>71.67</td>
<td>3.70</td>
<td>1.93</td>
</tr>
<tr>
<td>II 10% CRC</td>
<td>72.00</td>
<td>87.35</td>
<td>0.70</td>
<td>18.47</td>
<td>71.67</td>
<td>3.75</td>
<td>1.85</td>
</tr>
<tr>
<td>III 12% CRC</td>
<td>73.33</td>
<td>89.54</td>
<td>0.70</td>
<td>18.43</td>
<td>73.33</td>
<td>3.99</td>
<td>1.80</td>
</tr>
<tr>
<td>IV 14% CRC</td>
<td>79.67</td>
<td>98.48</td>
<td>0.61</td>
<td>19.71</td>
<td>78.67</td>
<td>3.98</td>
<td>1.79</td>
</tr>
<tr>
<td>V Commercial pig feed</td>
<td>69.67</td>
<td>94.39</td>
<td>0.71</td>
<td>18.03</td>
<td>61.67</td>
<td>3.39</td>
<td>2.10</td>
</tr>
<tr>
<td>cv, %</td>
<td>17.95</td>
<td>9.40</td>
<td>11.03</td>
<td>11.07</td>
<td>14.25</td>
<td>14.42</td>
<td>13.26</td>
</tr>
<tr>
<td>F-Test ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
</tbody>
</table>

Table 3. Digestion coefficient and total digestible nutrient (TDN) in CRC.

<table>
<thead>
<tr>
<th>Nutrients</th>
<th>Total Nutrient per 100 kg</th>
<th>Digestion coefficient (%)</th>
<th>Digestible nutrients per gram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein</td>
<td>15.41</td>
<td>65.20</td>
<td>10.05</td>
</tr>
<tr>
<td>Crude fiber</td>
<td>2.48</td>
<td>38.62</td>
<td>1.15</td>
</tr>
<tr>
<td>NFE</td>
<td>53.99</td>
<td>46.57</td>
<td>25.14</td>
</tr>
<tr>
<td>Ether extract</td>
<td>2.78</td>
<td>75.20</td>
<td>4.70</td>
</tr>
<tr>
<td>Total digestible nutrients (TDN)</td>
<td></td>
<td></td>
<td>41.04</td>
</tr>
</tbody>
</table>

Table 4. Production performance of finisher pigs fed with different levels of CRC in the diets.
### Table 5. Dressing Percentage (%) and backfat thickness of pigs fed with different levels of CRC.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Average liveweight (kg)</th>
<th>Average dressed weight (kg)</th>
<th>Dressing percentage (%)</th>
<th>Backfat thickness (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I 0% CRC</td>
<td>95.50</td>
<td>52.12</td>
<td>54.57c</td>
<td>3.00</td>
</tr>
<tr>
<td>II 10% CRC</td>
<td>80.00</td>
<td>49.50</td>
<td>61.84b</td>
<td>2.50</td>
</tr>
<tr>
<td>III 12% CRC</td>
<td>91.00</td>
<td>56.50</td>
<td>62.18b</td>
<td>2.25</td>
</tr>
<tr>
<td>IV 14% CRC</td>
<td>94.00</td>
<td>59.50</td>
<td>63.28b</td>
<td>1.66</td>
</tr>
<tr>
<td>V Commercial pig feed</td>
<td>86.00</td>
<td>56.00</td>
<td>65.12a</td>
<td>2.83</td>
</tr>
</tbody>
</table>

Means with a common superscript are not significantly different at 1% level of probability.

### Table 6. Return above feed cost of live finished pigs fed with different levels of CRC as component of the diets, Pesos.

<table>
<thead>
<tr>
<th>Item</th>
<th>Treatment</th>
<th>0% CRC</th>
<th>10% CRC</th>
<th>12% CRC</th>
<th>14% CRC</th>
<th>Commercial pig feed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total liveweight, kg</td>
<td></td>
<td>99.00</td>
<td>90.33</td>
<td>91.67</td>
<td>99.33</td>
<td>88.00</td>
</tr>
<tr>
<td>Sales of finished pigs, P₁</td>
<td></td>
<td>5,940.00</td>
<td>5,420.00</td>
<td>5,500.00</td>
<td>5,960.00</td>
<td>5,280.00</td>
</tr>
<tr>
<td>Total feed consumed, kg</td>
<td></td>
<td>228.73</td>
<td>223.83</td>
<td>237.33</td>
<td>261.04</td>
<td>191.61</td>
</tr>
<tr>
<td>Cost of feed consumed, P²</td>
<td></td>
<td>2,041.94</td>
<td>1,883.19</td>
<td>1,975.92</td>
<td>2,144.58</td>
<td>2,741.04</td>
</tr>
</tbody>
</table>

**Starte**

| Feed consumed, kg                 |                            | 32.40  | 32.17   | 34.03   | 34.38   | 29.27               |
| Cost of feed/kg, P                |                            | 10.62  | 10.12   | 10.03   | 9.93    | 16.00              |
| Amount                            |                            | 344.09 | 325.53  | 341.29  | 341.36  | 468.37             |

**Grover**

| Feed consumed, kg                 |                            | 125.00 | 120.00  | 130.00  | 148.33  | 100.67             |
| Cost of feed/kg, P                |                            | 8.87   | 8.37    | 8.27    | 8.18    | 14.00              |
| Amount                            |                            | 1,108.75| 1,004.40| 1,075.10| 1,213.37| 1,409.33           |

**Finisher**

| Feed consumed, kg                 |                            | 71.67  | 71.67   | 73.33   | 78.33   | 61.67              |
| Cost of feed/kg, P                |                            | 8.22   | 7.72    | 7.63    | 7.53    | 14.00              |
| Amount                            |                            | 589.10 | 553.27  | 559.53  | 589.85  | 863.33             |

Return above feed cost, P = 3,898.06 3,539.81 3,524.08 3,815.42 2,538.96

1. At selling price of P60/kg liveweight
2. Include cost of collection and processing of CRC which are itemized as follows:

1. Collection of CRC  P100.00
2. Drying of CRC (P100.00/Man-Day for 3 days)  P300.00
3. Transportation (Gasoline)  P100.00
4. Milling fee (300 kg for P200.00)  P200.00

**TOTAL**  P600.00

Cost of processed CRC per kg (P600.00/300 kg)  P2.00

### Table 7. Average cost of feed per unit gain-in-body weight of pig fed with different levels of CRC.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Average cost of feed per unit gain in body weight (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Starter **</td>
</tr>
<tr>
<td>I 0% CRC</td>
<td>17.01</td>
</tr>
<tr>
<td>II 10% CRC</td>
<td>23.60</td>
</tr>
<tr>
<td>III 12% CRC</td>
<td>19.29</td>
</tr>
<tr>
<td>IV 14% CRC</td>
<td>19.13</td>
</tr>
<tr>
<td>V Commercial pig feed</td>
<td>29.29</td>
</tr>
</tbody>
</table>

ns = Not significant;  ** = Significant at 1% level

Means with a common superscript are insignificantly different at 1% probability level.
pigs given diets with CRC was attributed to lower unit feed cost and not necessarily due to better feed conversion or heavier final weight. This implies that more economical and profitable pig feeding can be made possible with the use of CRC in the diet.

3. Summary

One of the potential threats to the environment is slaughter wastes in general and rumen contents in particular. Recycling these wastes and using it as feed ingredients to livestock may be a good alternative to handle this foreseen problem.

This study was conducted to evaluate the feeding, nutritive and profitability values of using CRC in the diet of pigs to rationalize its potential use. The study on CRC included percent recovery, proximate analysis, digestion trial, feeding experiment, dressing percentage, cost of feed per unit gain in weight and return above feed cost.

It was found out in the study that the average percent recovery of CRC is 25%. Proximate analysis and digestion trial revealed potential nutrients and feeding values. The dressing percentage of pigs given CRC diets were statistically better than those pigs given feeds with no CRC in the diet. Thinner backfat were observed in pigs given CRC diets. Moreover, profitability was higher in pigs given CRC diets when compared to those pigs given commercial feeds.

These findings highlighted the possibility of CRC inclusion in the diets of pigs which is comparable or even better in terms of production performance and profitability than pigs given no CRC in the diets and commercial feeds. Therefore, CRC as abattoir wastes could be tapped and recycled for pig feeding as a localized alternative to climate change mitigation.

References

**Agbibinnulig: An Iloko Cultural Resource in Managing Water Problems in Rice Farming**

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1. Introduction

Rice culture has been ingrained in Philippine history even before Spanish colonization times and until today’s global era. Rice in the Filipino culture involves not only a staple diet but also a symbolic metaphor of life and culture of the Filipinos [4]. Rice becomes a symbol of power and a scientific journey across the ages where it has been linked to poverty and development that includes beliefs, customs and rituals. And like a journey, rice farming culture is not bereft of problems. The rice farming journey in the Philippines showed that commercialization was not the main threat to this culture but that of irrigation problems [2].

In studying irrigation problems in the Philippines, [7] identified different sociological factors related to rice farming and irrigation where he pointed out that for rice and irrigation problems to be solved there is a need for farmers to communicate well and to cooperate with each other because to him irrigation is not much of a “water problem” but also that of a “people problem.” With his study he proposed the solution to irrigation problems must rely on socio-structural reform in planning, designing and implementing irrigation projects with close coordination and participation of both the National Irrigation Administration and the farmers.

Another dimension of rice farming and irrigation shows the rich cultural make up of the Philippines. Rice cultivation as mentioned by [1] has started before pre-colonization era and was ingrained with the collective culture of the different ethnolinguistic groups of the Philippine islands. Collective culture which is manifested in the working together of people for a common good is seen in several Filipino traditions such as the bayanihan. Other local studies on rice farming and water irrigation showed that water and rice are considered to be sacred and must be preserved by best practices among the ethnolinguistic groups. So among the Ifugao’s of the Cordillera they practice customs in the payoh or rice terraces and the Tukukans of Bontoc practice the collective irrigation process through the ugu or reciprocal labor cooperation [5, 3].

For this study agbibinnulig is the local equivalent of bayanihan or the ugu, the mutual self-help custom of the Filipinos. The study aimed to look at the potentials of this custom in coming up with local and effective solutions for water problems that has been plaguing communities especially with the onset of climate change, specifically El Niño among the different localities in the Philippines. Rice farming thus becomes vulnerable to this global scenario. However, local tradition of agbibinnulig showed that rice farming problems on irrigation is the best local cultural resource management strategy.

2. Research Methodology and Design

Qualitative research methodology was utilized in this study to bring out local experiences and insights and at the same time generated themes that enhance the potential socio-cultural practice of agbibinnulig for managing water problems in rice farming. Location of the research was done in Baggao, Cagayan for problems and complaints on water and for the agbibinnulig practice; I conducted an ethnography study in San Manuel, Isabela. Both locations are situated in northern Luzon which is locally populated by the Ilocano speaking people. Ethnography was done through informal interviews, document analysis, visual methodology and participatory observation. Case study was the research design employed to come out with local experiences in the two ili (villages/communities). Preliminary data gathering was done from August to December 2010 and in-depth immersion in San Manuel, Isabela culminated in 2011.

3. Results and Discussion

**Riri Ti Danum (Water Problems): Case Experiences in Baggao, Cagayan**

Baggao’s context shows that the National Irrigation Administration (NIA) is 48 barangays in the municipality. The municipality has a total of 92,060 hectares where 7,000 hectares are used for rice farming. With this total area, only 50% of the areas get water. There are five ways where these farms get water which are through (a) communal irrigation system which is dependent on rain, (b) small scale irrigation system (SSIS), (c) small water impounding project (SWIP), (d) small farm reservoir and (e) private pump wells.

With Baggao’s water problem, the following cases mentioned below show that water problems do have a far
reaching effect to well-being and economic development of each individual and community.

**Case Study 1.** Water conflicts lead to relationship conflicts and loss of life. In Bagao, Cagayan a murder took place due to irrigation problems where access to water source was seen as the root cause of the argument between two parties which escalated into murder.

**Case Study 2.** Unequal access of water among farmers is observed where farms with nearer proximity to irrigation sources or surong benefit while farms away from the irrigation sources or murdong have limited access to water and may only resort to water from rain or secretly get water at night from National Irrigation Administration. The president of Badang Farmers’ Irrigation Association mentioned that ‘ti kinabassit ti danum, mapuwersa ti tao nga haan agbigay’ (because of very limited water, people are then forced not to give). Even if there are schedule of water usage, it is not being followed and people are not giving but are being stingy to one another in terms of water resources due to the dilemma of preserving one’s source of livelihood and sustenance which is the rice farms.

**Case Study 3.** Barangay Lasilat of Bagao, Cagayan experienced similar problems caused by limited access to water resource which usually results to a difficult relationship among neighbors and that of the feeling of helplessness among farmers as they continue to rely on limited water available and to the onset of rains. Many farmers are hoping that a change of irrigation usage rules and procedure may bring better water resource management to the community.

**Case Study 4.** Baggao’s National Irrigation Administration’s negative experience on its water resource management is largely due to very limited water resource in the municipality largely caused by depleting conditions of Cagayan’s watersheds due to deforestation and denudation brought about by kaingin (burning of forest to use burned trees as charcoal products). Another problem pointed out is that a portion of the member farmers using the water resources do not follow the rules of water usage. Some farmers do not cooperate with the rules and the taxes imposed reasoning that they should not pay because they are not getting the enough water services for their farms.

**Agbibinnulig: Case Experiences of San Manuel, Isabela**

San Manuel is one of the 35 municipalities of Isabela which has a total of 19 barangays. The total land area for this municipality is 12,000 hectares where 83% of the land area is utilized for rice farming. According to Department of Agriculture, San Manuel is known for producing quality ‘certified palay (rice) seeds.’ San Manuel was also awarded in 2010 for Outstanding Irrigator’s Association for the whole Region II. The municipality is also known for its Cariada Harvest Festival and Banbanti Festival which are both festivals connected to rice farming.

**Case Study 5.** National Irrigation Administration San Manuel experience showed a very inspiring model of water management where they attributed the success of their rice farming and water management through basic organizing rooted in the socio-cultural practice of agbibinnulig which encompasses the spirit of unity and togetherness in accomplishing development goals in the context of rice farming. As presented in Fig. 1, agbibinnulig is present at the grassroots level of organizing Farmer Irrigator’s Group (FIG) where each group is then united into an Irrigator’s Association (IA). Leaders are elected to represent the farmers in the Council of Irrigators’ Association (CIA), which may comprise of five or more Irrigators’ Associations (IAs).

Noted in the agbibinnulig organizing and mobilizing strategy is the characterization of the practice through mannalon (rice farmer) participation and dialogue, cooperation and initiative. The process of agbibinnulig therefore gives them a sense of ownership of the process of water management as defined and designed by them from the planning to the implementation and the sustainability of the goals of the organized associations/ groups.

**Case Study 6.** A farmer’s association president shared his experience where he mentioned that agbibinnulig becomes the life blood of their irrigation organizations starting from the grassroots to leadership positions.
He mentioned that education, training and transparent meetings among them strengthen their agbibinnulig practice. It helped them reach their developmental goals which went beyond rice farming and water resource management such as acquisition of organizational and community development projects.

Case Study 7. A member of the farmers’ irrigators group shared that because of the trainings and meetings of their associations and groups they were able to achieve not only for the sole purpose of achieving equal access to irrigation but also other socio-economic dreams of expanding their livelihood opportunities by acquiring equipments and at the same time built their reputation as a model irrigation association within the region. Also, he pointed out that agbibinnulig in their organization brought them a sense of ownership that what they are doing is for the general welfare of all of them.

Agbibinnulig: A Model for Cultural-Resource Water Management in Rice Farming

The study showed that success of water resource management among mannalon or rice farmers depends on six major steps – namely:

1. Taripnong (meetings) – Occasional meeting among members is seen as a crucial step in providing avenues for members to be involved in their irrigation and development concerns in the community.

2. Panagtutungtong (dialogues) – Within meetings are opportunities of dialogue among member mannalon and officers in voicing out their concerns, problems and aspirations for their community.

3. Riri ken timpuyog (misunderstanding and cooperation) – the meetings also become an avenue to resolve existing riri (misunderstanding) and transform it into timpuyog (cooperation) towards the achievement of identified goals and projects of the associations or groups.

4. Pannakibadang (voluntary helping) – Initiative among the officers and members are expected in order that the next step which is agbibinnulig can be achieved. There is a sense of volunteerism to help for the common good which includes help in aspects of financial/economic, physical and moral support.

5. Agbibinnulig (community cooperative work) – Agbibinnulig becomes the product of all the previous steps which solidifies the implementation of the irrigators’ associations programs and projects.

6. Rangpaya (developmental progress) – As a result of all the steps done, rangpaya is achieved where development is seen as an overflowing effect of the agbibinnulig. This rangpaya can be pictured by a rice seedling that develops into a rice stalk with overflowing grains nurtured by the socio-cultural practice of agbibinnulig.

With all the identified steps observed in the San Manuel irrigation experience, agbibinnulig as the basis for organizing irrigators’ groups is seen as the crucial point towards a successful communal rice farming experience.

4. Conclusion

The study thus showed that agbibinnulig is a best practice worth replicating in the different irrigator’s associations and groups all over the Philippines. It is a practice that seeks solutions to water problems and enhances ownership among community members. The effect that agbibinnulig creates a ripple effect of rangpaya (developmental progress) in the community that in the long run improves the well-being and socio-economic development of the community.

Thus, it is imperative that the National Irrigation Administration must capitalize on this socio-cultural resource management in order to ensure the effective implementation of its programs and projects and at the same time empower communities to help themselves achieve rangpaya.

References


Installation of Participatory Guarantee System (PGS) for Organic Farming Practitioners in Nueva Vizcaya Province, Philippines

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Keywords: Participatory Guarantee Systems (PGS), Organic Agriculture, Organic Farming, Installation, Certification, Climate Change, Mitigation, Sustainable, RDE Plans, Food Security, Small-Scale Farmers, IFOAM/MAELA, MASIPAG

1. Introduction

Agrikulturang Pilipino (Agri-Pinoy) is the overall strategic framework for the agricultural services and programs of the Philippine government for 2011-2016. The four guiding principles of the program are food security and self-sufficiency, broad-based local partnerships, sustainable agriculture, and support services from farm to table. Its priority thrusts include organic agriculture, irrigation services, extension services, establishment of trading centers, and public-private partnerships.

The Organic Agriculture Act (Republic Act 10078) of 2010 provides the development and promotion of organic agriculture in the Philippines. It is the policy of the state to promote, propagate, develop further and implement the practice of organic agriculture in the Philippines that will cumulatively condition and enrich the fertility of the soil, increase farm productivity, reduce pollution and destruction of the environment, prevent the depletion of natural resources, and further protect the health of farmers, consumers and the general public.

Organic agriculture is an endeavor that protects, saves and sustains all the living components within its system. In order to promote and propagate this sustainable practice, a comprehensive involvement of different stakeholders - local government units (LGUs), peoples' organizations (POs), non-government organizations (NGOs), and individuals and groups who are willing to do other pertinent activities, and documentation and evaluation of the program, is crucial in research, development and extension (RDE) activities in line with the national organic agriculture RDE agenda.

Participatory Guarantee Systems (PGS) are locally focused quality assurance systems. Producers are certified based on active participation of stakeholders built on trust, social networks and knowledge exchange [2]. The system was coined after the IFOAM-MAELA International Workshop on Alternative Certification in Torres, Brazil held in 2004 and attended by more than 40 participants representing programs from 20 countries. This is a tool for improving socio-economic and ecological conditions by encouraging small-scale production and processing techniques. It is a certification system defined as “guaranteed or reliably endorsed.”

At present, more than 20 countries, including the Philippines, have PGS initiatives as alternative to third party certification especially for small-scale organic farmers. In Nueva Vizcaya, PGS was organized in 2012 through the efforts of Global Link Management Institute (GLMi) of Japan in partnership with the Philippine Rural Reconstruction Movement (PRRM), and Magsasaka at Siyentipiko para sa Pag-unlad ng Agrikultura (MASIPAG). This initiative of organizing the Nueva Vizcaya Participatory Guarantee System (NVPGS) is realized through the project “Support to Improve Livelihood of Farmers through Production of Organic & Reduced-Chemical Produce in Nueva Vizcaya” funded by the Ministry of Foreign Affairs (MoFA) of Japan through Grant Assistance for Japanese NGO projects.

The accreditation of organic certifying bodies or entities (e.g. NVPGS) is needed in order to uphold the existence of binding production standards and certification procedures. Only the products that are produced and certified according to the relevant standard can be sold and labeled as “organic.” The first and second party, the community based and participatory guarantee system side by side with third party certification are recognized by law, thus, PGS is a system of guaranteeing quality as part of empowering farmers in the context of organic agriculture.

2. Discussions

The Four Guiding Principles of Organic Agriculture

PGS believes in the four guiding principles of organic agriculture - the principle of health to prolong and enhance the health of soil, plant, animal, human and planet as one and indivisible; the principle of ecology which is based on living ecological systems and cycles, work with them, emulate them and uphold them; the principle of fairness toward building relationships that ensures equitability with regards to the common life situation and opportunities; and the principle of care in managing and protecting in a precautionary and responsible manner the health and well being of current and future generations and their environment [1]. These principles could exist through...
the different support systems in organic agriculture (Fig. 1).

**Organic Agriculture for Farmer Resilience against Climate Change**

One of the programs of the government is to promote food security through farmer-based adaptive strategies. The Philippines promotes sustainable development in the countryside is through the adaption of organic farming practices. Organic farming enhances higher organic matter and water holding capacity of soil. It has a 26% more energy efficient than conventional farming and 28% more organic carbon compounds stored in soil, thus, lower losses due to less production cost.

Organic farming is a viable option for mitigating climate change. It can reduce greenhouse gas (GHG) emissions by 15-20% compared to chemical-based production systems [4]. In organic farming, the ban of mineral nitrogen from chemicals, crop diversification, and improved soil aeration all diminish emissions of nitrous oxide (N2O). Furthermore, organic farming maximizes the use of cultural, biological, and mechanical methods instead of heavy reliance on synthetic inputs. It therefore enhances soil organic matter, enabling the soil to capture and retain more water, making the system specifically resilient to climate extremes like drought and flooding [3].

**Importance of PGS Programs**

Third party programs are doing an excellent job at what they were designed for and have vastly increased the global market and awareness of organic products. PGS, as a complimentary method to third party certification, is essential to the continued growth of the organic movement especially if we want to include poorer small-holder farmers who are the most to benefit from organic produce.

Barriers to entry for third party Certification, including direct costs and paperwork, mean that many of the smallest and poorest farmers cannot participate. With the installation of the PGS, small-scale farmers can avail very low fees in the accreditation and certification processes amounting to Php 300.00 – Php 500.00 only, in comparison to third party certification which can range Php 40,000.00 – Php 100,000.00 per scope (Table 1).

**The Nueva Vizcaya Participatory Guarantee System (NVPGS)**

Nueva Vizcaya has established itself as the major producer of both tropical and temperate vegetables in Region 2, and currently derives revenues from vegetables and fruit orchards, especially citrus fruits. It is also considered as the “watershed haven” of the Philippines’ Cagayan Valley region.

The province installed PGS in 2012 as an alternative to third party certification. NVPGS currently takes the lead in the certification process of organic products in Nueva Vizcaya. In order to boost the spread of organic agriculture programs, the installation of the system helps to encourage more conventional farmers to advocate organic farming practices and eventually become organic farming practitioners.

As a result, 64 organic farming practitioners in
the province were accredited and a farmers’ market for organic products was opened to the consuming public last September, 2012. The market currently operates twice in a month (during Saturdays) in Bayombong, Nueva Vizcaya (Fig. 2). Expansion of market outlets was done in the NVSU campus and even at the Provincial Capitol during weekdays.

Most of small-scale farmers of the province belong to the indigenous peoples (IPs) like the Ifugao, Kankanae, Kalanguya, Ibaloy, Ibanag, Isinai and Iwak ethnic groups. They inhabited the highlands which are conducive for cool-season vegetable growing. These are the towns of Sta. Fe, Dupax del Sur, Dupax del Norte, Kayapa, Kasibu, and Ambaguio. Through the installation of NVPGS, the upscaling of existing production area for organic agriculture is being envisioned. Likewise, the establishment of organic markets or trading posts in other municipalities is on the shot-term plan.

Objectives and Key Principles of NVPGS

NVPGS shares the same objective with the third party certification - to provide credible guarantee for organic products. The only difference is the approach wherein under PGS, direct participation of farmers and consumers in the process are compulsory. The active participation of farmers and consumers means greater empowerment but also greater responsibility.

Generally, NVPGS aims to empower responsible farmers and other stakeholders who are involved in promoting organic agriculture in Nueva Vizcaya. Specifically it aims to:

1. strengthen farmers’ management over production, selling, processing and marketing of their organic produce;
2. improve soil and reduce greenhouse gas (GHG) emissions;
3. implement PGS based on Nueva Vizcaya Organic Standards;
4. ensure the integrity and quality of Nueva Vizcaya organic products;
5. facilitate the ease of member-accreditation to organic practitioners;
6. provide accessible and affordable certification for small scale farmers; and
7. increase farm productivity.

Process and Mechanism of NVPGS: A Multi-Stakeholder Partnership in Establishing PGS in Nueva Vizcaya

NVPGS is geared towards building organizational structures involving the different implementing bodies which will oversee and take responsibility in protecting the integrity of the organic products. A NVPGS Committee (i.e. Technical Working Group) was created to spearhead, plan, strategize and oversee the marketing initiatives of the network. Mainly, the committee is responsible for the following:

1. monitoring and analyzing experiences of accredited organic farmers;
2. planning, fund sourcing activities and devising common strategies for marketing of organic products;
3. implementing the strategies in areas of scope;  
4. facilitating formulation, finalization and harmonization of NVPGS Organic Standards and Manual of Operations;  
5. overseeing NVPGS installation and implementation;  
6. regularly planning and assessing NVPGS objectives and activities; and  
7. programming capacity building activities of the accredited organic farmers.

The Committee is composed of farmer-representatives (POs), private consumers, academe (NVSU), LGUs (MAOs and MENROs), OPAg, NGO (PRRM), DTI and DA-R02 (Fig. 3). It is headed by a Chairperson with representatives as members.

The NVPGS Committee (set of officers) takes charge for two years of operation (June 2012 to June 2014):

1. Chairperson : Agustin Lunag (NVSU)  
2. Vice-chairperson : Merlinda Calubaquib (PRRM)  
3. Secretary : Noralyn Busa (OPAg)  
4. Treasurer : Rufin Fernandez (LGU-MAO Kayapa)  
5. Auditor : Ireneo Basadre Jr. (LGU-MAO Kasibu)  
6. Information Officers : Alberto Pamatian (DTI) Maribel Bacena (NVSU)  

An orientation about PGS and series of trainings on organic farming technologies were conducted for the farmers and stakeholders involved. The purpose of the orientation is to derive a common understanding of the concepts, context, standards and underlying processes in the system. This was followed by a two-day on-site training on inspection and approval. The NVPGS Committee attended the inspection and approval training where the inspection and approval process, procedures, strategies and management were discussed.

The mechanisms of the guarantee systems include the following:

1. Farmers who will join the PGS must be oriented on the systems and be provided with a copy of the Organic Standards and Manual of Operations formulated by the NVPGS Committee.  
2. Upon joining the PGS, farmers must fill up and submit the application, farm maps and production profiles to the committee for evaluation.  
3. Inspection is based on the Organic Standards of the PGS group. Frequency of inspection is at least twice per cropping season. The first visit is during vegetative stage; second is during harvest; and the third is during post-harvest activities.  
4. Decision-making regarding the organic status of farmers will be decided by the Approval Committee based on the inspection reports submitted by the inspectors.
3. Conclusions

Participatory Guarantee Systems (PGS) in the Philippines are quality assurance initiatives that are locally relevant, emphasize the participation of stakeholders, including producers and consumers, and operate outside the frame of third party certification. Through a multi-stakeholder partnership in establishing a PGS, organic agriculture could be easily adopted and implemented by organic farming practitioners and advocates throughout the country. Installation of PGS in the grassroots is seen as a sustainable enterprise and can help in mitigate adverse effects of climate change.

References

Youth Mediated Communication Model: Site-specific Decision Support System under Climatic Change

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1. Introduction

Agricultural production is largely influenced by local environmental conditions and local cropping systems. Under the serious climatic change, site-specifically appropriate decision supports is particularly important for small scale farmers in rural areas. Local extension staffs are originally in charge of such site-specific decision support. However, their skills tend to be limited and the number of the staffs is insufficient in rural Asia. One solution is the use of ICT to remotely support local farmers. There were, however, a few obstacles in undertaking such a solution. These obstacles were language illiteracy of farmers, ICT illiteracy of rural people and lack of quantitative local information about environmental conditions and cropping status. This quantitative information was critical for remote experts to provide proper advices to farmers. Installing low-cost field monitoring systems [1] may help collecting this data. But we learned that it was still quite difficult for local people to maintain such systems by themselves. More importantly, such systems were not able to detect crop conditions such as diseases and pests which spatially and randomly emerge.

In this study, we proposed an idea of collecting site-specific field information by having children to operate as field sensors. We have completed two phases of the field trials in Vietnam as a part of the project to test the YMC (Youth Mediated Communication) model which is to transfer information to illiterate parents through their children who attend school [4, 5]. In this model, children bridged their parent farmers and remote agricultural experts. Children informed the issues in their parents' farming to the experts and conveyed the answers and suggestions from the experts to the farmers. In the process, the children maximally use computers available at a village center.

At the project site, Tra On region in the Vinh Long District, the major crop is paddy rice. In general, the rice yield in this region is relatively high but the grain quality is rather low, which results in low market price. In addition, the farmers tend to practice high input farming as they believe that high input assures high yield. Such high input practice has been causing serious environmental damage and aggravating their balance of payments. In fact, the Vietnamese government is now advancing a policy of sustainable agricultural production under the climatic change.

2. Field Monitoring by Children

Each child who participated in the project received a tool kit to serve as “an intelligent sensor”. The kit contained a thermo-hygrometer, a measuring tape, a leaf color chart, an insect plate, a mobile phone and a field notebook (Fig. 1). At the beginning, the children were taught how to use the tools including the mobile phone and fixed the thermo-hygrometer on the outside wall of their home at 1.5 m high where no direct solar radiation reached throughout a day. Children recorded temperature and humidity every morning before they went to school and sent the data to the project server by SMSs using the mobile phones. The mobile phones and top-ups were incentives for the children. In addition, they are also visited the paddies of their families twice a week in order to conduct the following observations (Fig. 2):

1) Measuring plant height by the measuring tape.
2) Recording leaf color by the leaf color chart.
3) Finding pests by swinging canopy and dropping them on the insect plate inserted into the canopy and, taking pictures of them by the mobile phone.
4) Visually observing canopy and plants and recording special findings such diseases by taking pictures of them.

The collected data were uploaded through the computers in the village center so that the remote experts could refer it to provide advices to their parents’ farmers.

3. Conclusions

The first phase in 2011 showed positive impacts of this model such as improving yields and reducing pesticide use. Rice yields of the farmers who participated in the project were 0.3-0.5t/ha higher than those who did not participate [3]. In the following year, less disease
Fig. 1. The tool kit for the children sensors. a: thermo-hydrometer, b: field notebook, c: mobile phone, d: measuring tape, e: leaf color chart, f: insect plate

Fig. 2. Child’s sensor in action.
occurrence was observed in the participated farmers’ fields. As a result, the farmers reduced the number of pesticide spray by 1-2 times [3].

The field information monitored by the children was definitely helpful for the experts to provide proper advices to the farmers. For example, leaf color information was a good indicator of plant nitrogen condition and helped the experts to estimate proper amount of fertilizer. The photographs taken by the children (Fig. 3) were also useful for the experts to identify diseases and pests in the fields. Mapping such disease and pest information on GIS can be a useful early-warning system in near future.

Through the trials, most of the children were serious in the monitoring activities as sensors and their data collection were somehow sustainable. Though some children made mistakes in the measurements, the data mistakenly acquired were usually clearly identifiable as outliers. We could expect that continuous children’s monitoring will enrich a local database with which we can develop a crop growth and pest emergence model [2] suitable for a particular site-specific location.

Children were flexible enough to learn how to use computers and mobile phone without any difficulty and they became used to using them rather easily. This fact also indicated that children could be key persons to extend ICT in rural Asia. Moreover, children were almost maintenance free as sensors in contrast to modern field monitoring systems such as Fieldserver [1].

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Development of Decision Support System for Suitable Crop Simulation in Northeast Thailand

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Summary: The uses of information technology in the farming and rural extension community in Northeast Thailand are receiving increasing attention because of the immense potential, it brings for improving the traditional practices with innovative strategies and suitable crop system in an effort to consider recent economic, environmental, and social crises in the rural sector. These innovative strategies include moving towards a technology-based suitable crop simulation system. A review of literature determines that, there is a concern over the limited availability of agriculture advisory or suitable crop simulated system, and also the high costs coupled with complex infrastructures, context tend to dilute the advantages of existing systems. This inspired to develop decision support system for suitable crop simulation to support in precision farming system including suitable crop combination with cost benefits analysis. The web portal is aptly christened as Decision Support System for Suitable Crop simulator (DSS4SCS). Emerging and promising information gathering and dissemination technologies such as; Information Communication & Technology (ICT) & Wireless Sensor Network (WSN) were utilized to obtain precise crop, weather and environmental data/information. This system also provides MetBroker and MarSim weather data for simulation. Currently, the collected data were used for predicting Rice, Cassava crops yield and optimum date for crop rotation or sowing. WSN was deployed in a farm field at Phea-fan Village, Northeast Thailand, which falls under Tropical Agro-climatic region of Thailand. The researches presented here is a part of an ongoing project of GRENE-ei “Climate change and Evaluation of Their Effects on Agriculture in Asian Monsoon Region”. Currently DSS4SCS is in operation/functions in an Institute for Sustainable Agro-ecosystem Services (ISAS) intranet environment.

Keywords: Decision Support System, CROP Simulation System, Crop Yield, Precision Agriculture and Climate Changes

1. Introduction

With inclement climatic conditions, and the much aware global climatic changes, the farming community is facing uncertainty in their livelihoods. The situation is more worrisome fragile in Northeast Thailand. The farming community facing uncertainties/problems are: radical information/knowledge about suitable crops within the same agro-climatic zones. Rural community needs timely information/assistance to combat the situation. Information and Communication Technologies (ICTs) and Sensor Network (SN) (distributed sensing units pertaining to weather, crop and soil parameters under micro-climatic conditions) are promising location specific information gathering and dissemination technologies towards developing solutions for majority of the agricultural processes. In addition, the embedded simulated weather data from MarkSim [3] will assist to simulate the suitable combination of crops in the above said agro-climatic zones. Interlinking these technologies promises to be an interesting combination for generating host of useful information for various agriculture and environmental applications.

2. Information Communication Technology (ICT)

Keeping in view the increasing demand of Information and Communication Technology (ICT) applications in the precision agriculture, this web-based tool has been developed. Presently, this web system is being developed in an intranet environment. The resulting system is intended to assist the rural extension community and farmers for vibrant and better decision making.

3. Sensor Network Technology

With the dawn of low cost sensor network (SN) technology, one can obtain micro-climatic parameters from a location specific/field, which will improve the agricultural decision making and managing strategies to contest the coercions from climate changes. Field Monitoring System (FMS) [1] extensively used in real-time agricultural monitoring for various agricultural aspects. Fig. 1 illustrates the schematic work flow and the components of FMS.

3. ICT, Sensor Network and MarkSim Integration

ICT interlinked with Sensor Networks technologies and combine with MarkSim promises to be an interesting combination for generating multitude of useful information for various applications such as precision agriculture, drought, disaster management/mitigation, early warning systems, real time weather and environmental information systems, etc.

Realizing the importance of this integrated system (Fig. 2), an initiative was taken up under the GRENE Programme to develop a Decision Support System (DSS) for suitable crop simulation, which will be named as ‘DSS4SCS’, to assist the farmers and rural extension officers for improving the rural livelihood, environmental sustenance and agriculture productivity which are attracting importance recently due to global climate change.

The DSS4SCS web-interface (Fig. 3) will have more advantages over the traditional systems: centralized control over data and model, universal adoptable and easy accessibility, interconnectivity, model propagation,
education platform, and more importantly interconnectivity/coordination/flexibility in decision making/participatory decision making.

4. Part of the DSS4SCS Applications

This DSS4SCS web based system currently, utilize the sensory information (weather/crop/environmental) / MarkSim/User own data in CERES/ Simulation Model Rice-Weather relations (SIMRIW) and GUMCAS models for Rice and Cassava respectively. The combination of crops simulation options depicted in Fig. 4. Plans are in afoot yet to developed full-pledge system.

1) DSS4SCS Cost Benefit Analysis

The proposed system could be an intrusion model in the present climate change scenario context. This system embedded with local agricultural market information, which helps the farming community to understand the profit/loss and it leads to make necessary and ubiquitous strategic decisions. Fig. 5 illustrates the screen shot of cost analysis module of DSS4SCS.

5. Results

In the cassava experiment, the observed root yield were about 67.74 and 62.56 ton/ha [2] whereas simulated 57.70 and 52.51 ton/ha. The results reveal that, simulated results are lesser then observed yield. It may due to middling input of fertilizer and organic inputs. Places are afoot to provide DSS4SCS results.
Fig. 3. DSS4SCS homepage.

Fig. 4. Suitable crop simulation option.
Fig. 5. Cost analysis with dynamic agricultural market information.

<table>
<thead>
<tr>
<th>S. No</th>
<th>Date of sowing</th>
<th>Date of harvesting</th>
<th>Observed yield (kg/ha)</th>
<th>DSSAT-simulated yield (kg/ha)</th>
<th>DSS4SCS Yield (kg/ha)</th>
<th>Cost Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>November 21, 2011</td>
<td>May 4, 2012</td>
<td>67.74</td>
<td>57.40</td>
<td>Yet to be done</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>December 21, 2011</td>
<td>June 1, 2012</td>
<td>62.56</td>
<td>52.51</td>
<td>Yet to be done</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Cassava observed and simulated results.

6. Other Uses

1. Dynamic weather/agriculture/environmental information system
2. Crop yield modeling
3. Agro-decision support system
4. Primarily climate change analysis
5. Suitable crop combination scenario
6. Cost benefit analysis

Acknowledgement

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References


Cassava Growth after Rice in Sandy Soils with No-Irrigation in Northeast Thailand

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1. Introduction

Most of the arable lands in Northeast Thailand are typical tropical, sandy, acidic, and infertile. Sandy loam and loamy sand soil surface textures cover 50% and 11%, respectively, of the total area of the region (Wattana, 2010). According to Koppen’s system, the climate belongs to tropical savanna with an alternation of rainy and dry seasons. The main crops have been paddy rice in the rainy season. Irrigation systems are not well established and a large part of the arable land, especially the paddy field, remains under rain-fed conditions [4]. Ninety five percent of agricultural activity in Northeast Thailand is carried out in rain-fed areas in [3]. Regarding the environmental conditions and insufficient water supply, in the dry season, cassava (Manihot esculenta) is selected to be grown after rice because cassava is a drought tolerant plant and well adapts to the poor soil conditions of the uplands in Northeast Thailand [1]. This study was conducted to (1) investigate the suitability of two cultivars of cassava (Rayong-11 and KU-50) that gain root yield in sandy soils 2) find out the land preparation technique and agricultural conservation practice for growing cassava under the environmental conditions in those field. A split plot design was used in this study. The cassava stems were transplanted on November 26th and November 29th, 2012 in Wang-wa and Phea-fan fields, respectively. In addition, soil samples were taken and their physical and chemical properties were determined. We observed and recorded growth of cassava monthly (data were recorded on 30, 60, 90, 120, 150, and 180 days after transplantation). At the data collection time point for the initial stage (30-day after transplantation), KU-50 resulted is greater growth than Rayong-11 in both study sites (for Wang-wa field, KU-50 was 86% and Rayong-11 was 70%, respectively, and at Phea-fan the KU-50 was growing well about 97.22% and Rayong-11 was 94.10%, respectively. And we also found that soil moisture is a main key factor of growth and survival of cassava within the early stage. Confirming further growth and yield, we will conclude which cassaca cultivar is more suitable between the two, and the technique that should be applied in fields of sandy soils, after the harvesting time in May and June, 2013.

Keywords: Cassava, Soil Moisture, Real-time monitoring data, Sandy Soil, No-Irrigation, Agricultural Practice

2. Materials and Methods

1) Study Areas

The field experiments were conducted in two study sites in the upper paddy field in Wang-wa village (16°11'53” N, 102°48’58” E) at a mean sea level of 206 m and Phea-fan village (16°34’10” N, 102°40’45” E) at 216 msl, both located in Khon Kaen city in Northeast Thailand (Fig. 1).

2) Soils and Land preparation

Soil samples were taken at 0-15 cm and 15-30 cm depths before transplanting cassava and the samples’ pH, organic matter (OM), total-N, available-P, exchangeable-K, cation exchange capacity (CEC), bulk density, field capacity (FC), and permanent wilting point (PWP) were determined. A five-wheel tractor was used for preparing the land, plowing, and making ridges. The row to row distance was about 8 m and the ridge height was about 0.4 m.

3) Cassava

The cultivars named “KU-50” and “Rayong-11” were used in this study. Mature stems were cut into 15-20 cm-long cutting. The cassava stems were transplanted on November 26th and November 29th, 2012 at the Wang-wa and the Phea-fan fields, respectively. We transplanted the cuttings with a space about 0.6 m between cuttings that form a single row. A split plot design was used in this study.

4) Agriculture Conservation Practices

The soil surfaces were mulched by using rice straw immediately after the transplantation on November 27 and November 30, 2012 for the Wang-wa and the Phea-fan fields, respectively.
5) Field Monitoring System (FMS)

A FMS (X-ability, Col, Ltd, Tokyo, Japan) had been running at the study sites. This system was composed of an automatic rain gauge, an anemometer, a temperature sensor and a camera. The data can be accessed and downloaded via a web server. The FMS sends the image data for the field via the camera at 12 pm (Thailand standard time) every day. By using this system, the meteorological data such as rainfall, solar radiation, wind speed, wind direction, air humidity, and air temperature can be continuously collected.

6) Soil Moisture Monitoring

The 5TE sensors of Decagon Co., Ltd. (http://www.decagon.com/products/sensors/soil-moisture-sensors/5te-soil-moisture-temperature-and-ec/) were used to monitor soil moisture hourly in the fields. All sensors were connected to an Em50 data logger. The soil moisture sensors were installed into soil at 4, 8, 16, 32 and 64 cm depths in each plot.

3. Results and Discussion

Table 1 and Fig. 2 show that:

1) KU-50 and Rayong-11 Cultivar

Growth and survival of cassava were observed at 30 days after transplantation (DAT). The results show that KU-50 grown much better than Rayong-11 in both of the study sites. We found that the mortality ratios for KU-50 and Rayong-11 were about 14% and 30%, respectively in the Wang-wa field. In the Phea-fan field, we observed mortality ratios of 2.8% for KU-50 and 5.9% for Rayong-11, respectively. The cassava stems were planted into the soil at a depth of between 8 and 10 cm, thus growth of cassava in the early stage should have been tightly associated with soil moisture content of the 0 to 10 cm depth soil layer.

2) Planting Cassava on Ridge and Non-Ridge

In the Wang-wa field, we found that the mortality ratio of KU-50 cutting planted on the ridge was 17% and the non-ridge part was 11%, meanwhile, in the Phea-fan field, the ratios were 2.6% and 3.0 %, respectively. As for Rayong-11 in the Wang-wa and Phea-fan sites, the mortality ratios for ridge were 40% and 6%, respectively, and for non-ridge part 19% and 6%, respectively.

3) Effects of Mulching with Rice Straw as an Agricultural Practice

The mortality ratio of KU-50 in the Wang-wa field was 16% and 12% for mulching and non-mulching treatments, respectively, and for Rayong-11, about 32% and 27%, respectively. In the Phea-fan field, we found the mortality ratio of KU-50 with mulching and non-mulching were about 2% and 3%, respectively, while though of Rayong-11 were 7% and 5% for mulching and non-mulching, respectively.

Fig.3 and Fig.4 show changes of soil moisture at depths of 4, 8, and 16 cm in the Wang-wa and the Phea-fan cassava fields, respectively. The results show that soil moisture has been continuously decreasing from October to December 2012 because of no rain during that period at both study sites. Fig.2 shows that the soil moisture content of the Wang-wa field was lower than the value of field capacity (FC), thus the cassava cuttings in the Wang-wa field were subjected to a water stress...
Table 1. Observed data on cassava mortality 30 days after transplanting of the Wang-wa and Phea-fan villages.

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Conservation practice</th>
<th>Ridge vs Non-ridge</th>
<th>Plot no.</th>
<th>Wang-wa (% mortality)</th>
<th>Phea-fan (% mortality)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KU-50</td>
<td>Mulching</td>
<td>Ridge</td>
<td>M1</td>
<td>37.04</td>
<td>2.78</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M4</td>
<td>11.11</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-ridge</td>
<td>M2</td>
<td>14.81</td>
<td>0.93</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M3</td>
<td>2.78</td>
<td>3.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total mulching death</td>
<td></td>
<td>16.44</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>Non-Mulching</td>
<td>Ridge</td>
<td>M1</td>
<td>6.48</td>
<td>3.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M4</td>
<td>12.96</td>
<td>1.85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-ridge</td>
<td>M2</td>
<td>24.07</td>
<td>3.70</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M3</td>
<td>3.70</td>
<td>3.70</td>
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<tr>
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<td>Ridge</td>
<td>M1</td>
<td>65.74</td>
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<td></td>
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<td></td>
<td>M4</td>
<td>32.26</td>
<td>2.78</td>
</tr>
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<td></td>
<td></td>
<td>Non-ridge</td>
<td>M2</td>
<td>17.59</td>
<td>6.48</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>M3</td>
<td>10.19</td>
<td>6.48</td>
</tr>
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<td></td>
<td></td>
<td>Total mulching death</td>
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<td>6.71</td>
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<tr>
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<td>Non-Mulching</td>
<td>Ridge</td>
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<td>22.22</td>
<td>4.63</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>M4</td>
<td>37.96</td>
<td>6.48</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Non-ridge</td>
<td>M2</td>
<td>36.11</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>M3</td>
<td>12.96</td>
<td>4.63</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total non-mulching death</td>
<td></td>
<td>27.31</td>
<td>5.09</td>
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<tr>
<td></td>
<td>Total of Rayong-11</td>
<td></td>
<td></td>
<td>29.63</td>
<td>5.90</td>
</tr>
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</table>

Fig. 2. Mortality (%) of cassava associated with mulching and non-mulching practices with rice straw.

Fig. 3. Changes of soil moisture at depths of 4, 8, and 16 cm in the Wang-wa cassava field.
problem. On the other hand, in the Phea-fan field, the values of soil moisture content at 4, 8 and 16 cm depths indicate soil water availability for the plant. The changes of soil moisture in the Wang-wa soil layers indicated that cassava was affected by a continuous water stress after the transplantation. Therefore, the mortality of cassava in the Wang-wa field was higher than in the Phea-fan field.

4. Conclusions

Soil moisture content at the depth of 4 to 8 cm soil layer is very important for survival of cassava at the initial stage following the transplantation. By using real-time monitoring data (FMS and soil moisture sensors), we found that continuous water stress affect the growth of cassava in the initial stage in the Wang-wa field. As a result, the surviving cassava in the Wang-wa field was indicated to be lower than in the Phea-fan field. We also found that KU-50 grow much better than Rayong-11 in the initial stage (until 30 DAT) under the same conditions of soil and climatic factors.

Acknowledgement

This work was partially supported by “Climatic Changes and Their Effects on Agriculture in Asian Monsoon Region” under the GRENE program of MEXT. We would like to thankful to the farmer in Khon Kaen province, Thailand.

References

Prediction System to Optimize Double Cropping of Rice and Cassava in Thailand

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Summary: The purpose of the NARO/ARC team for the GRENE-ei CAAM project is elucidation of the effects of climatic changes on major crops in the Asian monsoon region by constructing of an evaluation system using meteorological data and crop models. Especially, we take charge of development of a system that can simulate the cultivation under various conditions (e.g., cultivar, weather, and management). The input of this system is meteorological data and management data such as planting, fertilizing and irrigation observed or generated by co-institutes. The output of this system is harvesting data such as yield and growing period. Conversion from the input data to the output data is done by the crop models and the climate change parameters.

In the first year, we surveyed about major crop models in Thailand to decide which crop model to adopt for the system, and it was clarified that DSSAT was applied to several crops in Thailand. Last year, we developed a prototype system to optimize double cropping of rice and cassava in Thailand. This is a system where a part of a final version is implemented. This system includes rice and cassava module of DSSAT. As the input data for the system, solar radiation, air temperature and precipitation of 0.05 degree grid data in northeastern Thailand were prepared. This data was generated from actual data using space interpolation method by NIAES. The each crop model was executed 365 times while the transplanting date was moved by one day each time, and the maximum yield of each crop was displayed on Google Earth. The result of the system seemed to show the current state of the yield in northeastern Thailand, though the verification using detailed cultivating data is necessary.

Keywords: DSSAT, Rice, Cassava, 0.05 Degree Grid Meteorological Data

1. Introduction

A Japanese research project, “Climatic changes and the evaluation of their effects on agriculture in the Asian monsoon region (CAAM)” [5] under the “Green Network of Excellence (GRENE)” [4] program from the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan was started in 2011 and will be conducted until 2015. The purposes of this project are to improve the reliability of climate prediction, and to develop the necessary information platform to design adaptation and mitigation strategies in agriculture against the predicted climatic changes in the Asia monsoon region, which encompasses Thailand, Indonesia, Philippines, and Vietnam. Sixty percent or more of the world’s population lives in the Asia monsoon region, and the effects of the predicted climate changes on the region are expected to be quite serious, since most of the countries in the region are agrarian.

Five institutions in Japan participate in the CAAM project (i.e., Japan Agency for Marine-Earth Science and Technology [JAMSTEC], Tokyo Metropolitan University, the University of Tokyo, National Agriculture and Food Research Organization / Agricultural Research Center [NARO/ARC], and National Institute for Agro-Environmental Sciences [NIAES]), and together they research four subthemes.

1. The development of an agro-climatological database in the region’s developing countries (CCR1)
2. The impact of land-use / land-cover (LULC) changes on the Asian monsoon climate (CCR2)
3. The identification of climatic changes and the elucidation of their effects on agriculture based on a field survey (AER1,2)
4. The development of an information platform to design adaptation and mitigation strategies of major crops against the predicted climatic changes (AER3)

The NARO/ARC team (AER2) researches the subtheme of “Elucidation of the effects of the climatic changes on major crops in the Asian monsoon region: Construction of an evaluation system using meteorological data and crop models.” The purpose of this subtheme is to develop an “evaluation system for major crops in the Asian monsoon region affected by climate changes” (hereinafter referred to as the evaluation system) that can simulate the growth of major crops in this region.

2. The Evaluation System for the Effects of Climate Change on Agriculture

The structure of the evaluation system is shown in Fig. 1. There are main three components of the system: (1) A meteorological data acquisition function, (2) crop models and a crop model execution engine that executes the models, and a parameter set for climate change effect simulation, (3) result data save, display, and comparison functions.

The crop model execution engine is a backbone function to execute a crop model repeatedly with conditions represented by numerical expressions. The engine can execute various crop models implemented by using a framework, JAMF (JavaAgricultural Model Framework)
by exchanging similar program parts.

A crop model implemented by using JAMF [1] acquires mainly meteorological data obtained through MetBroker [8, 9, 11]. MetBroker — a type of mediation software that exists between applications and databases — can access many meteorological databases by a unified method that does not require a complex database access program. With MetBroker, a crop model can be used worldwide with meteorological database such as the U.S. National Oceanic and Atmospheric Administration (NOAA) and the Global Dataset of DR and TR (GD-DR&TR) database (all over the world data in one degree grid) without the need to code the access program of each database. MetBroker can access a new meteorological database simply by developing a driver program. Therefore, it becomes possible for the crop model to use data in a new database that the other CAAM teams (CCR1, AER3) will construct, by obtaining the data from MetBroker.

Because the resulting data generated by the evaluation system is saved in XML format, several types of display application development will be possible to meet user’s requirements. Moreover, the accuracy of the evaluation system will be able to be verified by comparing the result data and the cultivating data that the AER1 team will observe.

3. Prediction System to Optimize Double Cropping of Rice and Cassava in Thailand

A prototype system to optimize double cropping of rice and cassava in Thailand (Fig. 2) was developed as the mid-term result of this project. This system is an extended version of the “Simulator for Cultivation Possibility of Rice” [12, 15] developed for Data Integration and Analysis System (DIAS) project [2], and it is a part of the “Evaluation System for the Effects of Climate Change on Agriculture” (Fig. 1).

As a result of survey for major crop model in Thailand, it was clarified that Decision Support System for Agrotechnology Transfer (DSSAT) [6, 7] was applied to several crops in Thailand. Enhancement of the educational system in Thailand and the maintenance of crops and soil databases are the main reasons for the spread of the DSSAT to Thailand. This system includes rice [13] and cassava [10] modules of DSSAT (version 4.5 for Linux). The default configuration (i.e., cultivar, dates and amounts of fertilizer and irrigation) was used to execute, because the local cultivating data is not available currently.

The prediction system for DIAS used one degree grid data (only for land, about 15,000 points) whose distance between points is 100 km (Fig. 3 left). It was enough as this resolution, because the system simulated all over the world. The evaluation system for GRENE simulates in the Asia monsoon region, therefore it requires higher resolution meteorological data. As the input data for the system, solar radiation, air temperature and precipitation of 0.05 degree grid data (w100×h120=12,000 points, center point coordinates: 16°30′N,103°00′E) whose distance between points is 5 km in northeastern Thailand (Fig. 3 right) were prepared. This data was generated using spatial interpolation method by NIAES from actual data observed by TMD (The Meteorological Department of Thailand) and NOAA.

The each crop model was executed 365 times while the transplanting date was moved by one day each time, and the yield and growing period of each crop were recorded. Those data was summarized to maximum yield data, and displayed on Google Earth (Fig. 4). The left side of Fig. 4 is the rice grain yield, in case transplanting date is August 1 and maximum cultivation period is four months. The right side of Fig. 4 is the cassava yield, in case starting date is December 1 and harvest date is July 15. In the regions enclosed in the yellow circle, the yield of rice and cassava is more than other regions. These dates and periods were set based on the clopping calendar in northeastern Thailand (Fig. 5). The evaluation equation was decided based on such conditions:

> Harvest day of rice is not over end of November, because cassava should be planted on December;
Fig. 2. Structure of the prediction system to optimize double cropping of rice and cassava.

Fig. 3. The points of meteorological grid data displayed on a map.

Fig. 4. Results of the prediction system to optimize double cropping of rice and cassava.
More rice grain yield is better;
> Harvest day of cassava is between May and July; and
> More cassava yield is better.

4. Results and Future Plan

The result of this system cannot be currently discussed, because there is no local field data to compare and to verify the result. The comparison and verification between the result and the observation data are task for this year and next year. The field data and more wide-ranging meteorological data will be prepared by the co-institutes.

About thirty seconds were required to execute one point. Therefore, it took four days or more to the calculation of 12,000 points. The crop model execution should shorten the processing time by improving the execution method. Multithreading is one of the effective acceleration techniques, because the calculation of the crop model of each point is independent. The server in which the system is installed has 8 cores / 16 threads CPU, therefore about ten times speed-up can be expected.

NARO/ARC team’s research is proceeding based on a five-year research plan (Fig. 6).

In 2011, we surveyed the major crop models used in Thailand to embed them in the evaluation system and to execute them. As a result, it was clarified that DSSAT was applied to several crops in Thailand.

In 2012, JAMF was improved to enable the use of field observation data (meteorological data, soil moisture data, etc.), and to execute DSSAT.

In 2012-2013, a prototype of the evaluation system was constructed. The simulation of the growth of major crops will be performed under various conditions (e.g., cultivar, weather, and management), and the climate change effect will be shown.

In 2013-2014, the accuracy of the prototype system will be improved by comparing the results of the evaluation system, and the cultivating data that other teams will obtain in local fields.
In 2015, the evaluation system will be implemented as a Web application and deployed to the DIAS server. These applications will have good operability and visibility so that not only researchers but also administrative officers and farmers can use them.

5. Conclusion

At first, we introduced the “Evaluation System for the Effects of Climate Change on Agriculture”. The evaluation system will be developed to elucidate the effects of the climatic changes on major crops in the Asian monsoon region. JAMF and MetBroker that are our main research products developed in former projects will be used to develop the evaluation system.

Then, we introduced the “Prediction System to Optimize Double Cropping of Rice and Cassava” that is a part of the evaluation system. This system includes rice and cassava modules of DSSAT that is a major crop model in Thailand. As the input data for the system, solar radiation, air temperature and precipitation of 0.05 degree grid data (12,000 points) of northeastern Thailand generated by NIAES were prepared. We became possible to do a more detailed simulation by using this data. The range of gird data will be expanded to the Asian monsoon region in the future.

It took four days or more to the calculation of all points. Computing time will increase more and more when the area of meteorological data expands in the future. Therefore, the crop model execution should shorten the computing time by improving the execution method. Multithreading is one of the effective acceleration techniques, because the calculation of the crop model of each point is independent.

We hope to achieve the presence of an engineer and an administrative officer in each country who will obtain the information infrastructure necessary to design climate-change adaptation and mitigation strategies in agriculture by presenting detailed predictions of climate-change effects on farm products based on reliable future climate change.

Acknowledgement

This study was financially supported by the Japanese research project “Climatic changes and evaluation of their effects on agriculture in Asian monsoon region (CAAM)” under the “Green Network of Excellence (GREEN)” program of the Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan.

References

Development of Information Platform to Design Adaptation and Mitigation Strategies of Major Crops against the Predicted Climatic Changes in Asian Monsoon Region

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Keywords: Adaptation and Mitigation Strategies, Agro-Meteorological Database, Climatic Changes, GHG, Information Platform

1. Introduction

Agriculture in Asian monsoon region is not only influenced by global climate change, but also contributes to climate change by acting as a source for greenhouse gases (GHG). In Asian monsoon region, variations in temperature and precipitation due to climate change strongly influence crop productions. CH4 and N2O emitted from agricultural sector are two of major GHG from the land into the atmosphere. The necessity for designing adaptation and mitigation strategies of agriculture against the predicted climatic changes is increasing in Asian monsoon region in the resent years.

2. GRENE-ei Program

We attempt to construct the information platform which is used for designing adaptation and mitigation strategies of major crops against the predicted climatic changes in Asian monsoon region, under the Green Network of Excellence - environmental information (GRENE-ei) program. The outline of our research plan is as follows:

(1) We collect data of meteorology, soil-information, land cover and agricultural statistics, and also compile agro-climate change scenarios in Asian monsoon region.
(2) Using these data, we evaluate soil temperature and moisture of cropland for each meteorological station over Asian monsoon region, and also compile them as daily based data set.
(3) These data are summarized as database, which can be used as the agro-environmental information platform for adaptation and mitigation strategies.
(4) We will also make monitoring of GHG emission from cropland at several sites in Asian monsoon region, as the joint research with foreign Institute.

These studies will be made with the help of the other research teams of the GRENE-ei program.

3. Agro-Environmental Information in Japan

Here, we introduce some of the agro-environmental information platform in Japan.

1) Gams-DB

NIAES has developed an agro-environmental database for planning adaptation and mitigation strategies in Japan. Name of this is gams-DB (Ghg Agro-stat MeteoCrop Soil-information Data Base) [1], which can be used on the website http://agrienv.dc.affrc.go.jp/. The gams-DB includes four kinds of data: agro-meteorological data, soil-information data, greenhouse gases data (CH4, and N2O), and agricultural statistics data in Japan.

2) MeteoCrop DB

In the agro-environmental information, agro-meteorological data is one of the most important information for designing adaptation and mitigation strategies of agriculture. We have developed an agro-meteorological database coupled with crop models (MeteoCrop DB) for studying the impacts of climate change on rice (Oryza sativa L.) in Japan (http://Meteo Crop.dc.affrc.go.jp) [2].

MeteoCrop DB consists of daily meteorological data at the Automated Meteorological Data Acquisition System (AMeDAS) stations (about 850 sites across Japan) from 1980 to 2013 and those at the about 160 surface meteorological observatories from 1961 to 2013. These stations cover the whole of Japan and are the main components of the meteorological observation network of the Japan Meteorological Agency. The daily meteorological data in the database consist of both general meteorological elements (air temperature, wind speed, precipitation, sunshine duration etc.) and agro-meteorological elements (solar radiation, humidity, downward longwave radiation, potential evaporation etc.). Since the latter elements are critical for rice production but are not measured at the AMeDAS stations, they are estimated for each AMeDAS location from the observed sunshine duration and the observed elements at the neighboring surface.
meteorological observatory. The models of micro-meteorology in crop canopy [3, 4] and rice growth [5] are run in combination with the agro-meteorological data to estimate the daily mean water temperature in a rice paddy during the growth period, the diurnal change in rice panicle temperature during the flowering period, and phenological stages of the rice plants.

The agro-meteorological data and the model estimation in MeteoCrop DB will facilitate the analysis of the effects of current climate change and variability on rice production, contributing to the risk assessment for future rice production and developing new technologies to adapt to the predicted climate changes.

4. Example of Usage of Agro-Environmental Information

1) Increasing Trend of Air Temperature in Japan and China

By using the daily agro-meteorological data on the MeteoCrop DB, we analyzed the recent agro-environmental characteristics in Japan. The 65 monitoring AMeDAS station were selecteded on the basis of the local land use around stations [6]. Then, we examined the increasing rate of annual air temperature during recent 28 years (1980-2007) for the 65 monitoring stations. Increasing trends were found in both the daily mean (Tmean), daily maximum (Tmax), and daily minimum (Tmin) air temperatures, and the largest increasing rate of Tmax attained 1.6 °C/25 years in southern-western Japan [6]. The increasing rate of air temperature strongly depended on season. Larger temperature increasing rates were found in spring (February) and autumn (September and October) seasons.

Increasing trend of air temperature in China was also examined by using the meteorological data at the about 200 observatories in China. The largest temperature increasing rate of annual Tmax attained 2 °C/50 years (1957-2006) in the northern part of China.

2) National-Scale Estimation of CH4 Emission from Rice Paddies in Thailand using the DNDC-Rice Model and GIS data

In order to estimate nationwide CH4 emission from rice paddies in Thailand using the DNDC-Rice model, we have started to collect datasets required, such as seasonal CH4 flux, crop calendar, paddy area distribution, soil type, and meteorological conditions. A long-term meteorological data in Thailand are collected and summarized as database in the GRENE-ei program.

Acknowledgement

This study is financially supported by the “Green Network of Excellence - environmental information (GREEN-ei)” program and “Research Program on Climate Change Adaptation” by the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan.

References

An Evaluation of Soil Temperature and Moisture Model in Agricultural Land in Japan

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1. Introduction

Soil temperature and moisture are essential environmental variables to evaluate not only crop growth, but also soil fauna dynamics and organic matter decomposition. But the number of observation station measuring soil temperature and moisture are quite rare compared to the general meteorological station. Therefore, we estimate soil temperature and moisture by heat and water balance model with using general meteorological data. In this presentation, we will introduce model validation results based on observed data.

2. Materials and Methods

The model used in this study was improved version of one-dimensional multi-layer model [1]. Daily mean, maximum, minimum air temperature, vapor pressure, precipitation, wind speed, incoming short and long wave radiation are required as model input data. In addition, soil type and its physical property, such as field capacity, saturated hydraulic conductivity, and maximum water holding capacity at observation point are also needed. We selected meteorological station at the National Agricultural Research Center for Hokkaido Region and used data openly available on the web [2]. The soil type at the site has volcanic ash soil, physical parameters of soil had been determined from observation [2, 3].

3. Results and Discussions

Seasonal variations in daily mean soil temperature and moisture at 10 cm depth in 2008 are shown in Fig. 1. The daily and seasonal variation of soil temperature was fairly simulated by the present model (Fig.1. (a), RMSE=1.27 °C). The soil moisture estimation also shows high accuracy overall (RMSE=0.025 m³ m⁻³), but there are somewhat differences around DOY100 between observation and evaluation (Fig.2. (b)). The reason for these differences is that model estimated snow disappearance date was about 10 days earlier than that observed, then we are considering improving the snow model. Fig. 2 shows an example of (a) daily mean soil moisture and temperature profiles. Both soil temperature and moisture profiles are consistence with observation. For the future, we will apply this model for many sites in Japan.

Fig. 1. Seasonal variations in daily mean soil temperature (a) and moisture (b) at 10 cm depth in 2008. Dotted and solid line indicates observation and evaluation, respectively.
Fig.2. Vertical profile of daily mean soil moisture (a) and temperature (b) on DOY164, 2008. Open square and closed circle indicates observation and evaluation, respectively.

References


Greenhouse Gas Emissions and Carbon Intensity for
Supersweet Corn Production of Thailand

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Summary: This study aims to evaluate carbon intensity and its associated greenhouse gas emissions in supersweet corn production at Khao Hin Sorn Royal Development and Study Center (KHS), Chachoengsao Province, east of Thailand for 2004/05 cropping year. The diesel fuel was considered in estimation of energy consumption. It was used for machinery and irrigation systems in corn farming at KHS. For greenhouse gas (GHG) emissions, the CO₂, CH₄ and N₂O emissions from soil surface were measured by static closed chamber method from dry evergreen forest (NF) plot as reference, corn cultivation plots proposed to produce the fresh ear of corn with application rate of compost at 30 t ha⁻¹ yr⁻¹ (CF) and supersweet corn cultivation plots proposed to synthesize the hybridization of corn (CS). This plot was applied with compost in high rate of 50 t ha⁻¹ yr⁻¹. Carbon emissions from agriculture inputs such as chemical fertilizer, green manure and compost applications were also estimated. The result was evaluated in the value of carbon intensity for corn production. The CO₂, CH₄ and N₂O emissions from soil were estimated in NF, CS and CF plots. The total CO₂ equivalent (CO₂-eq) emissions estimated from the total of CO₂, CH₄ and N₂O emissions by using Global Warming Potential (GWP) were 43.27, 47.30 and 50.59 t C-eq ha⁻¹ yr⁻¹ for NF, CS and CF soil, respectively. The amounts of soil organic carbon stocks (1m depth) were 23.45, 41.55 and 26.47 t C ha⁻¹ for NF, CS and CF soil, respectively. For the fuel use, the total diesel fuel use for machinery and irrigation was 173 and 60 liters ha⁻¹ yr⁻¹ in CS and CF plot, respectively. Totally CO₂ emissions for corn plantation combined between direct fossil energy uses and chemical utilization application was 1.73 and 10.19 t CO₂ ha⁻¹ yr⁻¹, respectively. Thus, the carbon intensity in supersweet corn production was 7544.44 and 8724.82 g CO₂-eq MJ⁻¹ for CS and CF, respectively. The result from this study could conclude that the GHG emissions in CS and CF, which were under agricultural practices, were higher than in the forest plot. This can conclude that the carbon intensity of corn plot for fresh pods production (CF) was consumed in term of energy consumption more than the corn plot for synthesizing hybridization (CS).

Key words: Carbon Intensity, CO₂, CH₄ and N₂O Emissions, Supersweet Corn, Compost

1. Introduction

The management of agricultural ecosystems can result in changes in carbon fluxes, including changes in soil organic carbon (SOC) and associated greenhouse gas emissions (GHG) emissions [8]. Thus reducing GHG emissions in agriculture can provide a window of opportunity for the other sectors to develop alternative technologies whereby their rates of GHG emissions can be decreased, and they can also assist in carbon sequestration and intensity. Carbon intensity is the amount of carbon by weight emitted per unit of energy consumed. It is one of the most important indexes in measuring a country’s GHG emission. To analyze change mechanisms is therefore critical as it provides policy-makers with a clear understanding of the impact of factors that contribute to GHG emission. It can also provide detailed information for future energy strategies and GHG emission reduction policies. However, most studies of change in carbon intensity focused on research conducted in developed countries and not those developing [3]. It is argued that in fact it is more important to analyze the carbon intensity change of developing countries, because it would aid in optimizing fuel-mix and economic structure. Moreover, it could provide detailed information on mitigating the growth of energy consumption and the related GHG emission, in order to avoid following the path of “first pollute the environment and then take counter measures” [4].

We hypothesized that corn cultivation emitted certain amounts of greenhouse gases and such emissions could be potentially reduced or offset by other activities in production system. Therefore, knowing how much and from which components of the cultivation system is a prerequisite. This paper presents the results of case study that examined carbon intensity in energy utilization in terms of fossil fuels; diesel and chemical utilization and subsequent GHG emissions associated with corn agriculture practices in Khao Hin Sorn Royal Development and Study Center (KHS), Chachoengsao Province, Thailand. The objectives were to: (i) collect and synthesize the available information on energy use and chemical utilization for the estimation of carbon intensity in supersweet corn farming, and (ii) estimate greenhouse gas emissions under difference managements of supersweet corn farming.

2. Material and Methods

2.1 Experimental site

This was located at the Khao Hin Sorn Royal Development and Study Center (KHS) Panom Sarakham District, Chachoengsao Province, eastern Thailand (771646N, 1520600W and 100 m a.s.l.). The experiments
were designed to investigate the carbon intensity from CO₂, CH₄, and N₂O emissions by closed static chamber method. There were 3 plot sites for study as follows:

1) Native Forest plot (NF) was a dry evergreen forest type with an area of 0.9 ha. The forest plot was used as the reference of no fossil fuel uses. The area has been preserved as community forest for more than 100 years without any significant land use change.

2) Corn plot for fresh pods production (CF) has been treated to produce the fresh pods of supersweet corn under experimental plots. The area of plot was about 0.25 ha. The fertilizer managements were operated both chemical and organic fertilizer application. This soil was composed with compost at 30 t ha⁻¹ yr⁻¹.

3) Corn plot for synthesizing hybridization in supersweet corn (CS) were purposed to produce varieties of seed production. The area of plot was about 0.25 ha. This soil plot was managed as intensive management with high rate of compost application. This has been treated with compost at 50 t ha⁻¹ yr⁻¹.

These plots were divided into five sub-plots for soil and gas sampling during the current study period. The mean annual air temperature at the KHS site was 27.0°C, and the mean annual rainfall was 1273 mm (average for 1995-2004). The supersweet corn (Zea mays L. saccharata. cv. Chat Ngueng) was sown and harvested for biomass estimation in CF and CS plots.

For both CF and CS plots, Green manure (Canavalia spp.) was grown once a year after corn harvest and the fresh Canavalia biomass was incorporated into the soil plots. Corn was planted in CF and CS plots in June and harvested in August, 2005. The aboveground biomass was incorporated into the soil immediately after harvest. The plots were left empty for one month and then corn was planted as the second crop during October-December. For CS plot, urea, 15-15-15 and 18-24-24 fertilizer were applied at the rate of 1.5, 2.1 and 1.0 t ha⁻¹ yr⁻¹ for each cropping period, respectively. For CF plot, the applications of these fertilizers were 0.9, 0.8 and 0.3 t ha⁻¹ yr⁻¹, respectively.

2.2 Carbon intensity and GHG Emissions

The carbon intensity was estimated from the energy consumption of fossil fuel use included the GHG emissions from soils. The carbon emissions from all factors involved and significantly impacted the carbon flow under crop practices such as crop inputs were estimated. The agricultural input data (i.e. fertilizers and irrigation) were derived from the Experiment Station’s records and converted to CO2 emission rates using the default values given.

3. Result and Discussion

3.1 Soil Characteristics

Basic soil analysis indicated that soil texture for NF and CS plots was sandy. Soils of both plots were classified as Silicious, Typic Ustipsamment. For CF plot, soil texture was sandy loam and classified as Kaolinitic, Typic Kandiustalf.

3.2 Soil Carbon Stocks

Soil carbon stocks were estimated to the depth of 100 cm. The estimated amounts of soil carbon were 23.54, 41.55 and 26.74 t C ha⁻¹ in NF, CS and CF soil, respectively.

3.3 GHG Emissions from Soil Surface

GHG Emissions from soil surface in term of CO₂, CH₄, and N₂O fluxes were measured monthly in 2005. The average emission of CO₂ was 339.80, 411.75 and 393.02 mg CO₂ m⁻² hr⁻¹ for NF, CS, and CF plots, respectively. The total emissions for one year were 2,963.40, 3,631.90, and 3,429.80 g CO₂ m⁻² yr⁻¹, respectively. The flux values were converted from mg CO₂ m⁻² hr⁻¹, mg CH₄ m⁻² hr⁻¹ and g N₂O m⁻² hr⁻¹ to ton CO₂ ha⁻¹, ton CH₄ ha⁻¹, ton N₂O ha⁻¹, respectively, and the total carbon emissions were estimated in 3 seasons including summer (Mar-Jun), rainy (Jul-Oct) and Cool season (Nov-Feb). All CO₂, CH₄ and N₂O emissions were estimated in CO₂-eq (equivalents) using the global warming potential (GWP), which determines the relative contribution of a gas to the greenhouse effect. The GWP (with a time span of 100 years) of CO₂, CH₄, and N₂O is 1, 21 and 310, respectively. The GHG emissions of CO₂, CH₄, N₂O and CO₂ -eq were determined from the different methods of agricultural managements in experimental plots at the KHS site. According to these assumptions and methodology, the CO₂-eq estimated for individual plots were 43.27, 45.75 and 49.40 ton ha⁻¹ in NF, CS and CF, respectively (see Table 1). These indicated that the GWP in CS and CF, which were under agricultural practices, was higher than in the forest plot.

3.4 C emissions from machinery and agricultural inputs

C emissions were estimated from GHG emissions in the unit of CO₂-eq. These were attributed to fossil fuels were estimated using existing C coefficients. Fossil fuel (diesel) used in machinery (farm tractor) and power pumps, which distribute irrigation water, was calculated only for corn plots (no fossil fuel using activities in forest). Carbon emissions from fertilizers were calculated using C emission factors for N, P₂O₅ and K₂O fertilizer.

3.4.1 C emissions from machinery and irrigation

The C emissions from diesel fuel were estimated from the value of C emission factor of 21.95 Kg C GJ⁻¹ and the net heating value applied was 36.24*10⁶ J lit⁻¹. From the result, the value 0.7955 kg C lit⁻¹ was used to estimate C emissions from the machinery and irrigation practices.

The emission factor for diesel fuel use was estimated for purposes in agriculture was 0.7955 kg C lit⁻¹. For
machinery, the amount of diesel fuel used for one year cultivation was 173 and 160 lit ha-1 for CS and CF plots, respectively. The estimated C emissions from these fuel uses were 0.14 and 0.13 t C ha-1yr-1, respectively. On the other hand, irrigation of crops consumed 855 and 800 lit ha-1 of diesel in CS and CF plots, which corresponds to 0.68 and 0.64 t C ha-1yr-1 in CS and CF plots, respectively.

3.4.2 C emissions from fertilizer application

For the estimation of C emissions from fertilizer application, the values of C emission for 1 kg of N, P2O5 and K2O - fertilizer application were 2404, 448 and 443 g CO2 kg-1, respectively [7]. In literatures, the value of C emission factor for fertilizers greatly varies [10] reported the values of 857.5, 165.1 and 120.3 g CO2 kg-1 for N, P2O5 and K2O fertilizer, respectively. The value of emission factors applied by [5] in Europe also varied widely depending on production technology [11]. For emissions from the fertilizers 15-15-15, the values were 400, 400, and 400g CO2-eq kg-1 of N, P and K fertilizer uses, respectively. Furthermore, the emission values for urea (46-0-0) production in Europe ranged from 913.0 g CO2-eq, 1326.1 g CO2-eq [5] and 4018.9 g CO2-eq kg-1 of N [2]. In this study, the values given by [7] were applied because of the similar fertilizer uses (urea and 15-15-15).

The annual fertilizer inputs of the CS plot as urea (46-0-0), 15-15-15 and 18-24-24 were 1.5, 2.1 and 1.0 t ha⁻¹, respectively. Accordingly, the corresponding emissions were 0.45, 0.28 and 0.18 t C ha⁻¹, respectively. The total C emission from fertilizer use for the CS plot was 0.91 t C ha⁻¹. Similarly, the amounts of these fertilizers applied for CF plot were 0.9, 0.8 and 0.3 t ha⁻¹. The emissions estimated in total of 0.26, 0.10 and 0.06 t C ha⁻¹, respectively. The total emission from fertilizer use for the CF plot was 0.42 t C ha⁻¹. In summary, the CO₂ emissions from agricultural inputs combined with irrigation and fertilizer practices were 1.59 and 1.06 t C ha⁻¹ in CS and CF plots, respectively.

3.5 Carbon intensity in supersweet corn production

The estimation of carbon intensity was calculated in the weight of carbon per British thermal unit (Btu) of energy. The result was showed in Table 3. The GHG emissions per yield of supersweet corn farming were 4.90 t CO₂-eq t⁻¹ in CS and CF, respectively. For the carbon intensity, the result found that GHG emissions were emitted from CS and CF plot in 4.90 and 10.67 g CO₂-eq MJ⁻¹, respectively.

Table 1. CO₂ emissions (t CO₂ ha⁻¹), CH₄ emissions (t CH₄ ha⁻¹), N₂O emissions (t N₂O ha⁻¹) and CO₂-eq (t ha⁻¹) from NF, CS and CF soil plots in each season in 2005 (standard deviations are shown in blanket).

Table 2. CO₂-eq emissions from surface soil, machinery and agricultural input in supersweet corn farming in NF, CS and CF plot.

Table 3. CO₂ emissions from fertilizers (t CO₂ ha⁻¹), CH₄ emissions (t CH₄ ha⁻¹), N₂O emissions (t N₂O ha⁻¹) and CO₂-eq (t ha⁻¹) from NF, CS and CF soil plots in each season in 2005 (standard deviations are shown in blanket).
Conclusions

This study evaluated the carbon intensity in energy utilization in terms of fossil fuels; diesel and chemical utilization and subsequent greenhouse gas emissions associated with supersweet corn production. The result from this study could conclude that the GHG emissions in CS and CF, which were under agricultural practices, were higher than in the forest plot. This could conclude that the carbon intensity of corn plot for fresh pods production (CF) was consumed in terms of energy consumption more than the corn plot for synthesizing hybridization (CS).

Acknowledgement

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References


Table 3. GHG emissions per fresh yield and carbon intensity in supersweet corn farming in 2005 at KHS experimental site.

<table>
<thead>
<tr>
<th>Supersweet corn plot</th>
<th>CS</th>
<th>CF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corn yield (fresh pod yield) (t ha⁻¹)</td>
<td>9.66</td>
<td>4.74</td>
</tr>
<tr>
<td>Diesel fuel use in corn production (lit ha⁻¹ yr⁻¹)</td>
<td>173.00</td>
<td>160.00</td>
</tr>
<tr>
<td>Diesel fuel energy in corn production¹ (MJ)</td>
<td>6,269.52</td>
<td>5,798.40</td>
</tr>
<tr>
<td>GHG emissions (t CO₂-eq ha⁻¹ yr⁻¹)</td>
<td>47.30</td>
<td>50.59</td>
</tr>
<tr>
<td>GHG emissions per corn yield</td>
<td>4.90</td>
<td>10.67</td>
</tr>
<tr>
<td>Carbon intensity (g CO₂-eq MJ⁻¹)</td>
<td>7,544.44</td>
<td>8,724.82</td>
</tr>
</tbody>
</table>

¹ converted from 1 liter = 36.24x10⁻⁶ J [1]


Remote Sensing of Carbon Dioxide Concentrations (XCO₂) Over the Philippines Using SCIAMACHY Level III Data

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Summary: In 2002, the remote sensing instrument Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY) was launched into space via the European Space Agency (ESA) Environmental Satellite (ENVISAT). SCIAMACHY is currently the only remote sensing instrument capable of measuring XCO₂. XCO₂ is the column-averaged mole fraction of CO₂ that is derived by dividing the number of CO₂ molecules by the number of oxygen molecules, a proxy for air. The dataset used in this study has a spatial and temporal resolution of 0.5° X 0.5° (gridded) and one month. The study is the first in the Philippines and employs SCIAMACHY level III dataset covering years 2003 to 2005. Despite the strict requirements of SCIAMACHY filtering software, substantial data were obtained for use in the study. Maps and graphs showed varied XCO₂ levels at various parts of the country and at certain months. The dataset was further analyzed and compared with CO₂ in-situ data for Mauna Loa in Hawaii. Four key areas were pinpointed to further describe XCO₂ in the country. Various anthropogenic factors were put forward as contributory to natural sources.

Key words: Carbon Dioxide, SCIAMACHY, Philippines

1. Introduction

Detailed knowledge on CO₂ and its fluxes through data acquisition from continental-regional to more specific national/state levels is important to properly project each country’s own carbon emissions. Such predictions would be a reliable basis for longterm local planning and policy development that are cognizant of international ones, as in Kyoto Protocol. However, while carbon dioxide is easily blamed for its drastic effects on climate, understanding and quantification of CO₂ at national to local levels are limited, spurring uncertainties in the process. Contributory to these uncertainties is the sparseness of ground-based network with a lack of high frequency surface observations in continental regions outside North America and Europe [7] for use in regional and national planning. This means that highly precise data regarding these gases are available, albeit provided by only few land-based remote sensing facilities, and which are usually limited in scope.

The Philippines is thought to be vulnerable to effects of climate change. However, existing policies on climate change and greenhouse gases are heavily based on more generalized global data, as local database is lacking. The emergence of satellite-based remote sensing instruments, with a capability to operate globally are projected to perform regional measurements to derive carbon dioxide concentrations in the atmosphere to augment existing global knowledge and understanding various applications.

In 2002 the European Space Agency (ESA) Environmental Satellite (ENVISAT) hosted the launching of SCIAMACHY (Scanning Imaging Absorption Spectrometer for Atmospheric Chartography) into space. It records transmitted, backscattered, and reflected solar radiation from the atmosphere at 0.2 nm to 1.5 nm over the range 240 nm to 1700 nm and in select regions between 2.0 μm and 2.4 μm. SCIAMACHY has the ability to detect many trace gases through its high resolution and wide wavelength range. SCIAMACHY is the first and currently only imaging spectrometer which is capable of measuring solar radiation in the Near-Infrared (NIR) and Short Wave Infrared (SWIR) spectrum. SCIAMACHY is able to detect and obtain concentrations data of CO₂, which is absorbed strongly in the IR (Infrared) and NIR regions.

The reliability of remote sensing technology, like SCIAMACHY to quantify CO₂ is at par with that of hardly-accessible land observation points. Garcia-Soto (2009) compared the global datasets for column averaged carbon dioxide dry-air mole fraction (XCO₂) collected by in situ facilities and by SCIAMACHY-ENVISAT, and found that the two datasets highly agree to one another, with typical discrepancy of only ≈1ppm. In 2007, [1] compared SCIAMACHY CO₂ measurements within CarbonTracker and found that year-to-year CO₂ changes can be determined with an accuracy of about 1 ppm year⁻¹. In this case, SCIAMACHY is advantageous since it can singularly obtain and monitor at great accuracy CO₂ anywhere in the globe.

This study analyzed the spatio-temporal distribution of dry-air column carbon dioxide mole fraction, also hereinafter referred to as XCO₂ over the Philippines using dataset generated by SCIAMACHY covering the first three years of the instrument’s operation. It used Level III dataset released by the University of Bremen in Germany, the principal investigator for SCIAMACHY products. Specifically, it discussed spatial concentrations and variability of X CO₂. The study also identified in the overall distribution the XCO₂ levels of four (4) key areas and related corresponding measurements to present potential CO₂ sources (e.g. industries, agricultural and forest lands), and compared them with other baseline data on carbon dioxide. Finally, it elaborated CO₂ concentrations over the Philippines through a time series model in order to evaluate seasonal trend and inter-annual variability.

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2. Materials and Methods

SCIAMACHY [3, 1] is the first satellite-born remote sensing instrument whose measurements are sensitive to concentration of the gases at all altitude levels down to the Earth’s surface [7]. SCIAMACHY collects data from three different viewing geometries: nadir, limb and sun/moon occultations. These provide total column values as well as distribution profiles both in stratosphere and troposphere for trace gases and aerosols. In remote sensing terms, radiation signals of a given gas molecule are strong in a certain light wavelength, hence its “signature” in the light spectrum. Signals of carbon dioxide specifically are strongest at IR and NIR bands, and SCIAMACHY is designed to extract the data collected in said wavelengths. This study is focused on measurements collected from IR and NIR bands.

In the spectral region, O₂ column is retrieved from 755-775 nm while CO₂, from 1558-1594 nm. The dry-air column (without water vapor) mole ratio for carbon dioxide (XCO₂) is obtained by dividing CO₂ measurements with simultaneously-measured molecular oxygen (O₂) in the atmosphere. Oxygen is determined as ideal proxy for air column because its mole fraction is known and is almost invariable. The formula for XCO₂ values is written as:

\[
XCO₂ = \frac{CO₂}{O₂} \quad \text{(molecules/cm²)}
\]

Where CO₂ is the retrieved absolute carbon dioxide in molecules/cm², O₂ is the retrieved absolute oxygen columns in molecules cm⁻² and O₂mf is the assumed mole fraction of oxygen used to convert the O₂ column into a corresponding dry-air column. Hence, O₂mf is a mixing ratio and is equal to 0.2095 [7]. But prior to this, SCIAMACHY raw measurements are applied with retrieval algorithms to facilitate the derivation of XCO₂. The principal investigator for SCIAMACHY, The Institute of Physics, University of Bremen has developed a retrieval technique called Weighting Function Modified Differential Optical Absorption Spectroscopy (WFMDOAS), a modification of a previous retrieval algorithm. Details of WFM-DOAS are elaborated [4, 1, 7]. WFM-DOAS is mainly responsible for the retrieval of the vertical columns (of oxygen and carbon dioxide) and elimination of observation errors influenced by the presence of clouds, aerosols and albedo, among others.

The study employed Level III Dataset of CO₂ dry-air column mole-fractions (parts per million per volume, ppm) generated by the SCIAMACHY/ENVISAT from January 2003 to December 2005. Level III means that the dataset have already been processed as consumer-ready product for use of third party research. It is a requisite that various quality checks and validation be employed prior to release of produced datasets, to assure the product’s integrity. Taken from nadir or down-looking observations, the data have a spatial resolution of 0.5° latitude x 0.5° longitude (gridded) and temporal resolution of one month.

The dataset was prepared for processing using MSExcel and then analyzed using other mapping software (GEBCO and Surfer) to evaluate XCO₂ concentrations and variability at different temporal and spatial scales. XCO₂ geo-reference data is used to map its distribution and variability over the geographic location and territory of the Philippines. Four key areas in the Philippines were pinpointed to represent its regions to facilitate the description of CO₂ concentration (Table 1 and Fig. 1). Selection was based on some considerations: two cities to represent urban/industrial zones and another two to represent the rural areas; areas to fairly represent geography of the Philippines, two in Luzon, one in Visayas and one in Mindanao; of which one represents rural-mountainous area, one rural-coastal, another for urban mountainous and also one urban-coastal. Another consideration for the

Table 1. Description of the four key areas.

<table>
<thead>
<tr>
<th>Area</th>
<th>Location</th>
<th>Rural / Urban</th>
<th>Mountainous / Coastal</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Manila</td>
<td>Luzon Island</td>
<td>Urban</td>
<td>Coastal</td>
<td>Capital City; highly industrialized; port area</td>
</tr>
<tr>
<td>2. Nueva Vizcaya (Bayombong)</td>
<td>Luzon Island</td>
<td>Rural</td>
<td>Mountainous</td>
<td>Ecotourism / Agricultural Province</td>
</tr>
<tr>
<td>3. Catarman, Samar</td>
<td>Visayas</td>
<td>Rural</td>
<td>Coastal</td>
<td>Agricultural</td>
</tr>
<tr>
<td>4. Davao</td>
<td>Mindanao Island</td>
<td>Urban</td>
<td>Mountainous</td>
<td>One of premier cities in the country; highly industrialized</td>
</tr>
</tbody>
</table>
Visayas region is that because majority of the smaller island provinces are concentrated therein. The study was also able to plot the kinetics of CO₂ mole fractions on a per key area, per month, and per year basis. Level of XCO₂ annual averages from the whole dataset were extracted by determining the point coordinates of the areas, and then matched to the closest possible coordinate in the dataset.

3. Results and Discussion

Philippine geography and climate are crucial factors in the derivation of XCO₂ measurements. The archipelago, aside from being parted administratively into provinces, towns and cities, is divided into three island groups: Luzon, the northern and largest; Visayas, the central area where the small islands are concentrated; and Mindanao, the southern part which is near Sabah Island in Malaysia. As optimal SCIAMACHY readings and spatial resolution (0.5° x 0.5° gridded) require cloud-free and vast land areas, measurements from the Visayas region may have been affected by the size of islands and the surrounding waters. The presence of clouds and aerosols may also have been contributory. Hence, most readings from these areas have been filtered out of the product. Further, atmospheric CO₂ data from surrounding seas have been detached.

The stringency of current quality filtering of SCIAMACHY data [7,1] resulted from the rejection of most measurements especially over the southern hemisphere (where the Philippines is situated). This translates to spatio-temporal data gaps, especially in the central islands (Visayas group) for the period 2003-2005. The presence of clouds, the inland seas as well as the relatively small land area of the islands are some of the considerations for the rejection of corresponding georeferenced and timed data even at the level I dataset. Notwithstanding the data gaps, XCO₂ data primarily covered much of the Philippines. The spatial variation of carbon dioxide concentrations also coincided to population density of the country. In a population density map generated by Center for International Earth Science Information Network (CIESIN, 2007), the areas with higher density (500-1000 km-² and >1000 km-²) matched well with the areas having above-average to high XCO₂ levels and vice-versa. Thus, it suggests that georeferenced XCO₂ data retrieved from SCIAMACHY (0.5° x 0.5° gridded) with higher concentrations were found in highly urbanized and industrial cities, where high level of population density and anthropogenic activity can be found (e.g., industry operations, public and private transportation emissions, energy consumption among others, can be found). Similar observations on regional XCO₂ elevations from anthropogenic activity were also reported by [7].

While basic knowledge of carbon dioxide fluxes posits that relatively lower XCO₂ levels can be found in rural and forested areas, high level of anthropogenic activity is not constrained to the cities, as the population is well distributed over the country, with many rural towns and communities occupying even the forested areas and the uplands. SCIAMACHY XCO₂ yearly averages are the largest over the tropical regions [7], and that it may be partially caused by retrieval errors due to undetected subvisual cirrus clouds that are common to such areas [6].

Such increase in places other than the urban areas may be attributed to some anthropogenic factors. Many households still engage in backyard and biomass burning for waste disposal and fuel. There also exist various transportation modes such as buses, jeepneys, and motorized tricycles which are also open to public as a government franchise for internal revenue and livelihood. Another is land conversion from alienable and disposable lands to agricultural lands (e.g. residential subdivisions) or from forested areas to farmlands. Persistence of swidden agriculture practice (called kaingin) in the uplands may also be contributory. Reduction of forestlands, being primarily responsible for XCO₂ uptake and processing, could have also caused the rise of XCO₂ levels. Spatial variations of XCO₂, especially over the Luzon and Mindanao islands and sparse readings over the Visayas group (Fig. 2). Of special interest is the XCO₂ signal recorded in Aklan-Capiz areas, (Visayas) and its adjacent areas.

Fig. 2. Annual Spatial Patterns of XCO₂ Concentrations over the Philippines. The images (left to right) above show the spatial patterns of carbon dioxide concentrations (XCO₂, in ppm) for years 2003, 2004, 2005, and a composite 2003-2005 map. Pixels have a spatial (grid) resolution of 0.5° x 0.5°. Color scale mapped XCO₂ values (in ppm by volume) are categorized as follows: Red – 385-395ppm or greater; Yellow – 375-385ppm; Green – 365-375ppm; Light Blue – 365-375ppm or lower; Dark Blue – data not available. Incidental data for Sabah and parts of Malaysia are also included in the lower-left area of the maps.
The 2003 and 2004 data for this area may have been filtered out by SCIAMACHY WFM-DOAS algorithm, since the region is composed of small islands, but it registered very high XCO2 concentration in 2005. While much of the area is still rural, one plausible explanation for the unusual XCO2 level of this area is the active tourism activity in the island of Boracay, home to one of the most sought-after beaches in the world.

**XCO₂ Seasonal Variability**

Over the 36-month period (January 2003 – December 2005), XCO₂ concentrations over the Philippines registered erratic (month-to-month) fluctuations without a distinct seasonality (Fig. 3). Further, SCIAMACHY measurements for September 2003 and June 2004 were filtered out most likely due to the presence of heavy clouds and occurrence of typhoons, aerosols, and other climatic phenomena on said periods. The measurements for said periods at 373.68 and 374.99 ppm, respectively, were derived using simple interpolation. To uncover trends hidden in the series, the 36-month dataset was converted into a composite time series (i.e. measurements for Januaries of 2003, 2004 and 2003 were averaged, and so on). Fewer values were considered by WFM-DOAS for the latter half of the year (July-December) when the wet season is usually occurring. Further, smaller and scattered areas like the Visayas group of islands, tend to have less set of monthly values, as contrasted with most parts of Luzon and Mindanao, where monthly averages are more pronounced and consistently available. From the available values covering minimum to maximum period of the 36-period time series, XCO₂ concentrations for the entire country increased by 2.025 % and the highest monthly concentration is recorded in November 2005 with 395.26 ppm. The “breathing” pattern of XCO₂ in the Philippines for 2003 to 2005 is that it starts rising slowly and peaks in May, dips down by July to September.

![Fig. 3. Time series of XCO₂ monthly averages from January 2003 – December 2005. Series in blue show the actual monthly measurements, superimposed to the series in red with interpolated measurements for September 2003 (9-2003) and June 2004 (18-2004).](image)

![Fig. 4. Comparison of XCO₂ levels of four key areas to the rest of Philippines. Upper-left: City of Manila, the Capital City located in Luzon; Upper-Right: Bayombong, capital town of Nueva Vizcaya (Luzon); Lower-Left, Davao City, a chartered city in Mindanao, and; lower-right: Catarman, a shown here are values of closest single-coordinate pixel XCO₂ measurements from minimum to maximum period extracted from the SCIAMACHY level 3 dataset for the Philippines. Also included per panel are three-year XCO₂ averages for key area and rest of the country.](image)
and begins to rise again by October or January. A very abrupt XCO₂ rise can be observed as the series approaches November-December. This may be explained by peoples’ heightened activity due to last-minute preparation for Christmas season. The locals and those overseas workers coming home tend to join the so-called “pre-“and “post-Christmas rush” to avoid inconveniences in shopping and overseas travel. In effect, a considerable increase in transportation, among others, can be observed.

High concentrations of CO₂ (385 – 395 ppm) are seen consistently throughout the months in industrialized areas such as Manila and Davao while moderate to above-moderate concentrations (365-375-385 ppm) were observed for rural areas and the rest of the country. For the areas where data were not available, CO₂ concentrations cannot be described using the present normalization and quality filtering processes for SCIAMACHY, as more relaxed algorithms (to allow measurements for regions with smaller surface areas are still under development. Nonetheless, additional description of key areas can be found in last section of this paper’s discussion.

4. Conclusions

While the country contributes to a small fraction only of total global carbon dioxide levels, this exercise was still significant as it identified in finer detail which areas can be sorted as either carbon sink or hotspot – baseline information that may be used for future studies and policymaking. The first of its kind in the Philippines, it also discovered which regions need further study, like the islands of Visayas and the province of Palawan in eastern-central Philippines. The study itself needs further analysis in the future – as the dataset will still evolve and improve. The strict retrieval and filtering processes of the young instrument greatly affected the data used in this study. The formation of the dataset was dictated primarily by constraints inherent in the strict retrieval algorithm, WFM-DOAS, which was used to filter out “dubious” measurements at considerable number of points, affected by clouds, aerosol, albedo, among others. The developers of the algorithm have yet to improve the software in order to make it even more powerful tool for assessing XCO₂ concentrations of smaller land areas. Despite the present strict requisites for a “good” measurement, i.e., a vast and cloud-free area (which hardly fits the geography of the archipelagic Philippines), the study has found that SCIAMACHY level III dataset for carbon dioxide is substantial enough to facilitate a more detailed observations of XCO₂ concentrations in the country. It is hoped that the retrieval system (WFM-DOAS) would be further relaxed and refined to accept measurements over smaller and cloudy areas like the Philippines’ Visayas regions.

The dataset covering 2006 to the present year is yet to be released by the principal investigator for SCIAMACHY products (University of Bremen) so the 36-month dataset needs more measurements to gain forecasting potential. Ultimately, when the datasets will be released regularly and promptly, a more rapid and up-to-date assessment is needed for academic and legislative reasons can be achieved.

Having been commissioned in 2002, SCIAMACHY on ENVISAT is now seen as the precursor to present and future satellite instruments dedicated to the study of greenhouse gases. Also, in the absence of ground-based instrument in the Philippines, it promises to be a viable tool in exploring the still-unknown aspects of carbon dioxide and other important greenhouse gases.

Acknowledgment

The author thanks the following people and institutions: Prof. Michael Buchwitz and University of Bremen IUP for the SCIAMACHY dataset; NOAA-ESRL for the Mauna Loa CO₂ in-situ dataset; Ms. Arshiela Gauuan and Ms. Marla Hernandez of NVSU and Mr. Tristan Dela Cruz of NVGCHS in the Philippines for help in the statistical analysis. The main author was given a financial aid from the University of the Basque Country. Special thanks to Professor Javier A. Loidi, Coordinator of the Master’s Programme at the University of the Basque Country. The study was carried out at the Spanish Institute of Oceanography at Santander.

References


Greenhouse Gas Emissions in Rice Paddy Fields in Japan and Thailand

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1. Introduction

Recent extreme climate events globally reported may largely be attributed to increases in greenhouse gases (GHGs) in the atmosphere. Methane (CH4) and nitrous oxide (N2O) are major GHGs emitted in agricultural fields other than carbon dioxide (CO2). In many monsoon Asian countries, rice is a staple food. Rice paddy fields are considered to be a major source of CH4 and N2O from agricultural activities since water management practices in rice paddy fields make soil both oxidized and reduced conditions [1]. In the field condition, soil temperature usually shows diurnal fluctuation. The dependencies of CH4 and N2O emissions on soil temperature in the mid-latitude temperate region [2, 3, 4] and in the tropical region [5] are reported that GHGs emissions generally increase as increases in soil temperature. If it is true, however, there has been no data reported indicating that GHGs emissions are larger in the tropical region than those in the temperate region because of higher soil temperature in the tropical region. We investigated GHGs emissions in rice paddy fields during a growing season both in the tropical Thailand and the temperate Japan.

2. Materials and Methods

Experiments were conducted in rice paddy fields in Kamphaeng Saen, Thailand (14.070556° N, 99.968056° E) whose annual average temperature was 27.6 °C and Hiratsuka, Japan (35.362769° N, 139.338073° E) whose annual average temperature was 15.4 °C. The fluxes of GHGs, i.e. CH4 and N2O, in the rice paddy fields were measured using the relaxed eddy accumulation (R.E.A.) or the conditional sampling method (Fig. 1). A gas flux, J (mg m-2 h-1), using the R.E.A. method was calculated as [6]:

\[ J = B \sigma_w (\overline{C_u} - \overline{C_d}) \]

where \( B \) was the empirical constant (=0.6), \( \sigma_w \) was the standard deviation of vertical wind speed (m s⁻¹), \( \overline{C_u} \) and \( \overline{C_d} \) were average gas concentrations carried by upward- and downward-wind (mg m⁻³), respectively, for 10 min in our case. Methane and nitrous oxide concentrations were measured every 10 min using a photo-acoustic gas monitor (model 1412, Innova Air Tech Instruments, Denmark). Vertical wind speed at 2 m high above the ground was measured with 10 Hz intervals using an ultrasonic 3-D anemometer (SAT540, Kaijo Co. Ltd., Japan). The rice paddy fields had the enough fetch over 50 m in both experimental sites. Air inlets for upward- and downward-wind were fixed close to the anemometer at 2m high above the ground. Solenoid valves and the gas monitor were controlled using a data logger (CR1000, Campbell Scientific Inc., U.S.A.). During measurements in the both rice paddy fields, Oryza sativa L. was grown.

Soil temperature at 10 cm deep from the soil surface at the both site was measured with type T thermocouples. Volumetric water content was measured with 20cm long time domain reflectometry (TDR) probes vertically installed into soil from the soil surface. Soil temperature and volumetric water content were recorded every 10min using a data logger (CR23X, Campbell Scientific Inc., U.S.A.). Atmospheric pressure was measured every 20 min using an atmospheric pressure sensor (RS-12P, Espec Mic Corp., Japan).

3. Results

During the flowering stage of rice plants, diurnal fluctuations of GHGs fluxes depending on soil temperature were shown in Fig. 2. Although there were large differences between soil temperatures (Fig. 2C) in both experimental sites, the magnitude of GHGs fluxes was similar in both CH4 (Fig. 2A), and N2O (Fig. 2B). The diurnal trend and the magnitude of CH4 flux were similar to those reported by [5].

It is well known that the flush of CH4 flux in peatland is triggered by low atmospheric pressure [7]. We also observed a similar phenomenon in a rice paddy field as shown in Fig. 3. The first CH4 ebullition was observed around the midnight of October 3rd when the atmospheric pressure decreased to 1,000 hPa. The largest CH4 ebullition occurred in the morning of October 8th when a big low pressure system with 980s hPa went though nearby the experimental site. The large amount of CH4 gas was...
Fig. 1. Diagram of relaxed eddy accumulation (R.E.A.).

Fig. 2. Diurnal fluctuations of CH$_4$ flux (A), and N$_2$O flux (B) depending on soil temperature at 10 cm deep (C) during the flowering stage in Hiratsuka, Japan and Kamphaen Saen, Thailand.

Fig. 3. CH$_4$ flux affected by the atmospheric pressure in Hiratsuka, Japan.
released from paddy soils when soil temperature increased and atmospheric pressure decreased less than $\approx 1,000$ hPa.

4. Conclusions

The R.E.A. system continuously measured CH$_4$ and N$_2$O fluxes in rice paddy fields in Japan and Thailand. The fluxes diurnally fluctuated as soil temperature diurnally changed. The magnitude of maximal and minimal CH$_4$ and N$_2$O fluxes in tropical Thailand was similar to that in temperate Japan. The ebullition of CH$_4$ was also observed in a rice paddy field in Japan when the atmospheric pressure decreased approximately below 1,000 hPa.

Acknowledgement

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References

Mitigating Greenhouse Gas Emission in Food-Energy Crop Rotations

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Keywords: Soil Organic Carbon, Crop Rotation, Natural 13C Abundance, Soil Aggregate, Energy Crop, Rice

Abstract

Effects of crop rotation in two case studies were investigated. The first case study was maize rotated with lowland rice. The soil has been cultivated with maize for more than 20 years. Changing from maize (C-4 crop) to rice (C-3 crop) has enabled us to follow the incorporation of C-4 carbon or C-3 carbon into different fractions of soil. The second case study was a rotation of lowland rice with maize or sweet sorghum. Greenhouse gas emission and soil carbon were then measured in these different crop rotations. Cropping change from maize to flooded rice resulted to increases in soil bulk density, methane emission and SOC content compared to that of maize-rice rotation and continuous maize. The total SOC after two cropping was 16.50, 20.88 and 19.35 ton C ha⁻¹ in the maize, lowland rice, maize rotated with lowland rice, respectively. The majority of SOC (ca. 65%) were present in association with the macro-aggregate (>250 μm) fraction, of which the fraction size of 250-500 μm contained the highest carbon concentration. After two croppings, the δ¹³C values of SOC were shifted towards the δ¹³C values of that rice straw when soil was incorporated with rice straw. The shift of δ¹³C values towards maize straw’s δ¹³C values was also observed in the case of maize straw incorporated into soil. In the second case study, soil was always acting as the net methane source when cultivated with lowland rice. However, when rotated either with maize or sweet sorghum, methane emission from lowland rice cultivated after maize or sweet sorghum decreased significantly. The total amounts of methane emission during croppings were 1,788.19; 2,053.99; 13,200.26; 1,946.48 mg CH₄ m⁻², for fallow-rice-fallow-rice; maize-rice-maize-rice; rice-rice-rice-rice and sorghum-rice-sorghum-rice rotation systems, respectively. These results demonstrate that crop rotation between upland-energy crop such as maize or sweet sorghum, and lowland rice could enhance soil carbon sequestration, and decomposition and incorporation of organic materials (maize and rice straw) into SOC was detectable within a short time period. Methane emission could also be significantly reduced when cultivating upland crops before lowland cultivation.

Keywords: Soil Organic Carbon, Crop Rotation, Natural 13C Abundance, Soil Aggregate, Energy Crop, Rice
Paddy Growth and Emission under Various Groundwater Levels

Budi I. Setiawan, Arief Irmansyah, Chusnul Arief, Masaru Mizoguchi

Abstract

Reducing uses of water in paddy fields under the System of Rice Intensification would produce occasional wetting and drying of the surface soils. These conditions would be affecting soil environments, releases of greenhouse gas and finally paddy growth. This research was aimed at finding how paddy grew and greenhouse gas emitted from the soil surface subjected to various groundwater levels. Herewith, experimental studies were conducted in 4 plots of paddy fields. The size of each plot was 4 m to 4 m with the soil depth was about 1 m. The water level in Plot 1 was maintained at -5 cm from the soil surface. In Plot 2, 3 and 4 water levels were decreased gradually as the plant grew until reached -20 cm, -25 cm and -30 cm, respectively. Measurements of water level, elongation of aboveground and belowground were carried out in 3 days-intervals. Box measurements of CH$_4$ and N$_2$O were conducted in 15 days-intervals. Data series of soil moisture and temperature and microclimate were analyzed with Artificial Neural Network (ANN) in order to figure out their influences on the plant growth and on the release CH$_4$ and N$_2$O. It was found that aboveground biomass responded negatively while belowground biomass responded positively to the lowering groundwater levels. It was also found that CH$_4$ emission decreased gradually from 140 to 60 mg/m$^2$/day as water levels was decreasing from 0 to -25 cm while N$_2$O emission was fluctuated around 80 µg/m$^2$/hour. The developed ANN model could describe clearly the patterns of paddy growth and methane emission under various groundwater levels.

Keywords: Paddy Field, GHG Emission, Water Level, Artificial Neural Network

1. Background

2. Materials and Methods

Soil Properties

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<th>Plot 3</th>
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Lines are Genuithen model
Dots are measured data

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3. Results and Discussion

4. Conclusions

5. Acknowledgments

6. References
Creating researchers network using APAN and SRII

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1. Introduction

One of Objects of Green Network of Excellence program (GRENE) is “the domestic leading universities work together to share research resources and research goals”. To achieve this, existing groups are utilized by members of GRENE-ei CAAM. The subject of NARO in GRENE-ei CAAM requires advanced technologies using the Internet. Therefore, Asia-Pacific Advanced Network (APAN, [1]) and Service Research and Innovation Institute (SRII, [2]) are selected by members in NARO.

2. Asia-Pacific Advanced Network

APAN is a non-profit association to connect research and education computer networks in Asia Pacific region. APAN is also referred as a backbone network. To encourage effective use of APAN backbone, APAN has 14 working groups in two areas (Table 1). Agriculture Working Group (AgWG) was established at the APAN Tsukuba in 1998 and has been one of most active working groups in APAN since then. For NARO subject in our project, APAN is suitable group as follows:

1. Many researchers in the field computer, computer network, and other information technologies exist
2. Sensor Network (SN) Working Group exists and can integrate existing sensor networks virtually
3. Earth Monitoring (EM) Working Group exists and can provide some satellite product

1) Taking a co-chair of APAN AgWG

A few years ago, the activities of AgWG became low, because chair and co-chair of AgWG became too busy to take care of AgWG. Unfortunately they neglected to elect new chair and co-chairs of AgWG, they must continue taking care of AgWG after their term was over. Behalf of APAN AgWG chair, I proposed an EM, SN, Ag WGs joint workshop, and a GRENE-ei CAAM, AgWG joint workshop in APAN 33rd meeting in Chiang Mai. And at the AgWG gourp meeting, Prof, J. Adiranayana (IITB, India), Prof. Yunen Wan (Taiwan), Dr. Pisuth Pipoonrat (NECTEC, Thailand), and I were elected as AgWG co-chairs.

Table 1. Working Groups in APAN (based on [3])

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2) GRENE-ei CAAM Related Activities

Table 2 shows GRENE-ei CAAM related activities in APAN meetings, 33rd in Chiang Mai, 34th in Colombo, and 35th in Hawaii.

Dr. Shin-ichi Sobue (JAXA, Japan) is leading “Asia-Rice” project monitoring rice field in ASIA, under the GEO-GLAM [4]. GRENE-ei CAAM also targeted rice in Asia monsoon region. His group in JAXA and NARO member of GRENE-ei CAAM started how to collaborate each other and this activity reported in the Working Group (WG) 2 “Agriculture and Food Security”, the 6th GEOSS Asia Pacific (GEOSS AP) Symposium in Ahmadabad [5]. Prof. Seishi Ninomiya is a co-chair of this WG In the 36th APAN meeting in Daejion, JAXA and GRENE-ei CAAM will have a workshop “Rice Monitoring in ASIA” as an EM an AgWG joint workshop [6].

In the 37th APAN meeting, will be held in Jakarta, a GRENE-ei CAAM and APAN AgWG joint workshop will be held.

In Asia-Pacific region, there is another R&D network, Trans Eurasia Information Network (TEIN [7]). Fortunately, TEIN pays attention to APAN AgWG activities, co-chairs APAN AgWG wish to create a good relationship with TEIN also.

3. Service Research and Innovation Institute

“SRII is led by senior leaders from major IT companies and is in close partnership with academia, research institutes, as well as government organizations from around the world.” [2]. And its mission is “Drive Research & Innovation for “IT Enabled Services for a Better World”. And expected participants are Professional Societies, Global Research Organizations, Major Universities/Institutes, and Government Organizations. SRII has a special interest group (SIG) on Agriculture. In Agriculture, the technologies so called “service oriented cloud” is an possible innovation Members of NARO are developing a kind of service oriented cloud for Agriculture under GEREN-ei CAAM. In APAN meetings several activities related service oriented could, such as Smart Agriculture (Thailand), Agriculture IoT (China), or Agriculture Could (Taiwan) were reported. Therefore, they invited me as a panel of this SIG in SRII India [8], and talking about APAN AgWG activities. But those activities sometimes do not have any relationship with private sector. Considering how to disseminate our results, we should create good relationships with private sectors.

Anyway, stakeholders of governments and private companies in each country are invited to SRII conferences. It seems that interacting with stakeholders through SRII
can support researchers and their network politically, financial, and/or technically if SRII success. A project related Agriculture IoT will be launched soon in India, but it is not sure SRII India contributes it or not.

4. Conclusions

Working as a co-chair of APAN AgWG, APAN is used for creating researchers network effectively to achieve one of GRENE objects. Attending SRII India, as a panel of Agricultural session, it seems that SRII will be used for creating network with private sectors and governments, and this network may be useful for creating and supporting researchers network in Asia Pacific region. GEOSS AP also provides good opportunities to create researchers network.

Acknowledgements

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References
