SUSTAINABLE BIOPRODUCTION

WEF 2011

CIGR International Symposium On

"Sustainable Bioproduction - Water, Energy, and Food"

September 19-23, 2011

Tokyo, JAPAN

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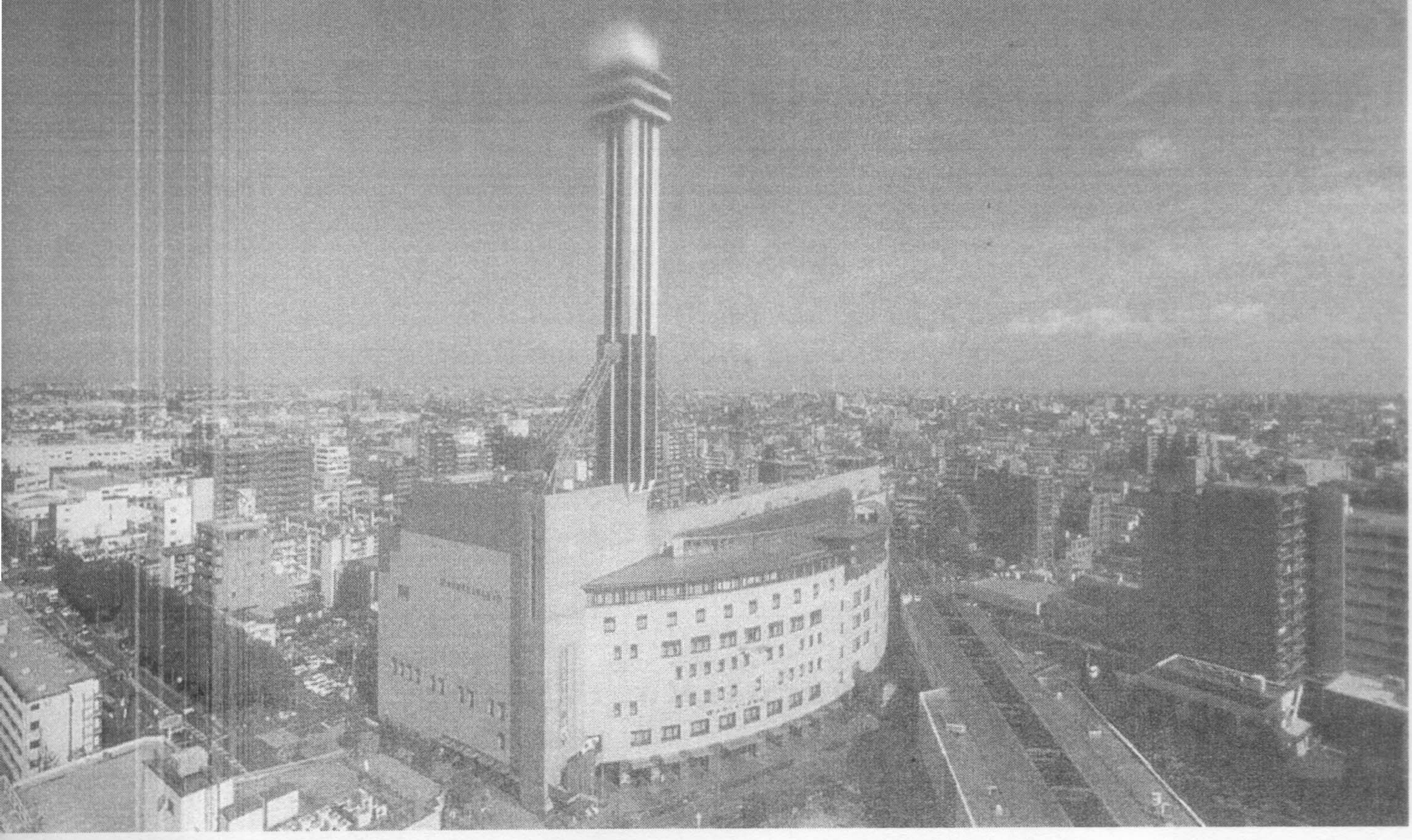

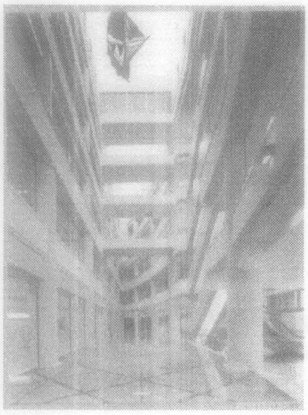

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Growing uncertainty over the future status of water, energy and food resources in light of the devastating scenario of global warming has led the world to strive to seek solutions for the perennial development of humankind. Recent developments in biomass technology have raised the unexpected issue of the crop resource trade-off between energy crops, feed crops and food crops. CIGR has been dedicated to developing world water resources, to modernizing world food production and to conserving our environment with the commitment of agricultural engineers and scientists from CIGR member nations. The challenge currently faced by us for the coexistence of humankind throughout the world is to find a method to balance our resource utilization and energy development; this task might well be termed as a CIGR mission.

In the year 2011, all engineers, scientists and affiliates from 7 technical sections of CIGR will meet in Tokyo to discuss the updated controversial issues on water, energy and food along with the latest technological development that the world would seek.

|ABOUT THE SYMPOSIUM|

The 2011 CIGR International Symposium on **"Sustainable Bioproduction - Water, Energy, and Food", September 19-23, Tower Hall Funabori, Tokyo, JAPAN** will bring together researchers and professionals interested in new ideas, engineering, and technologies used in Sustainable bioproduction systems. Attendees will be able to share ideas, theories, techniques, challenges, and concerns with peers and expand their professional networks worldwide. They will also have the opportunity to attend many joint activities. The symposium is open to researchers and engineers from all over the world as well as general publics those who are interested in the global issues with water, energy, and food.

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| CALL FOR PAPERS |

Abstract Submission Form

Important Dates:

Submission of abstract: July 1, 2010
Notification of acceptance: August 1, 2010
Initial manuscript submission: April 1, 2011
Critiqued manuscript returned to authors: June 1, 2011
Final camera-ready manuscript submission: July 1, 2011
Early registration due: July 1, 2011
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Authors are invited to submit a paper targeting one of the main topics: 1) Evaluation, Investigation and Utilization of Agricultural Productive Environment for Sustainable Bioproduction, 2) Increment of Safety, Security and High Quality of Food Production necessitated for Humankind, and 3) Environmental Preservation for Agricultural Production on Water and Energy. The paper should describe original work, including methods, techniques, prototypes, applications, systems and tools, reporting research results, and/or indicating future research and development directions.

What to do: Submit an abstract limited to 500 words, including the title of the paper. List the names and affiliated organizations of all authors in the abstract. The abstract should be self-contained, concise, and informative. It should describe the research objectives, methods used, and the major findings.

One of the authors will present the accepted paper during the workshop, and the paper will be printed in a preprint of the workshop. A few selected papers will be submitted to an CIGR Ejournal or the Journal Computers and Electronics in Agriculture based on the relevancy of research reported to be considered for publication as a peer - reviewed article. Selection will be based on the quality, relevance, and originality of the submitted paper.

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Contact to:

Prof. Taichi Maki (Chair of NOC), e-mail: maki.taichi.fe@u.tsukuba.ac.jp
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22B08

Field Network System to Monitor Paddy Fields in the System of Rice Intensification in Indonesia

Chusnul Arif*, Budi I Setiawan, Masaru Mizoguchi*, Ryoichi Doi*, Satyanto K Saptomo**, Ardiansyah***, Tetsu Ito***

** Department of Global Agricultural Sciences, the University of Tokyo, JAPAN*
(e-mail: chusnul_ar@yahoo.com, amizo@mail.ecc.u-tokyo.ac.jp; aroird@mail.ecc.u-tokyo.ac.jp; tetsu@iai.ga.a.u-tokyo.ac.jp)
*** Department of Civil and Environmental Engineering, Bogor Agricultural University, INDONESIA*
(e-mail:budindra@ipb.ac.id; ddody@yahoo.com)
**** Department of Agricultural Engineering, Jenderal Soedirman University, INDONESIA*
(e-mail: ardi.plj@gmail.com)

Corresponding Author :
Department of Global Agricultural Sciences
1-1-1 Yayoi, Bunkyo-ku, Tokyo 113-8657, Japan
Phone: +81-3-5841-1606
Email: chusnul_ar@yahoo.com

Abstract: The current study was performed for establishing a field network system (FNS) to monitor paddy fields in the System of Rice Intensification (SRI) environment in Nagrak Organics SRI Center, Sukabumi, Indonesia. FNS works as a remote monitoring system which field router equipped with an in situ camera and connected to meteorological and soil data loggers. Changes in soil conditions (moisture, electrical conductivity and temperature) and meteorological parameters were measured and monitored at intervals of 30 minutes. Then, the data and plant image were daily transmitted to a remote server by means of the Global System for Mobile communication (GSM) with the help of a newly developed field router. All data were made accessible online at http://emsa-sri.org as images in addition to numeric and graphic data. There were four experimental plots with different water management regimes; continuously saturated soil (CSS) in the first plot, incompletely saturated soil (ISS) in the second plot, moderate soil drying (MSD) in the third plot and severe soil drying (SSD) in the fourth plot. In the CSS regime, the soil was kept saturated or at water levels -5 to 0 cm depth as recommended by SRI training center in Indonesia; while for ISS regime, the soil was kept drier than the CSS regime at water levels of -15 to -5 cm depth. Moderate soil drying was applied at water levels of -30 to -5 cm depth in the MSD regime and the last regime (SSD regime), severe soil drying was applied at water levels -60 to -10 cm depth particularly from 70 day after transplanting. Based on the findings of the experiment along a single crop season, the FNS run well and was reliable in the monitoring of the plants, meteorological and soil parameters. However, stability of the field router depends on the field solar power supply and the Internet connection. In case there is problem in the Internet connection within data transmitting time, the images data were lost. The images data showed the series of SRI plant growth from a tiny seedling to a large cover area and facilitating evaluation of each growth stage. With the numeric data, the water productivity could be well determined and the values were 1.95, 2.01, 1.51 and 2.04 kg/m^3 for CSS, ISS, MSD and SSD regimes, respectively. In addition, the evaluation of water management regimes revealed that in the CSS and MSD regimes, the soil should be more saturated to gain more yield and water productivity particularly in the early stage to the crop development stage as occurred in the ISS and SSD regimes.

Keywords: System of Rice Intensification, Environmental Parameters, Irrigation system, Field Network System, Quasi-real time monitoring

1. INTRODUCTION

The challenges to raising rice productivity in Indonesia have been increasing due to the increased population and reduced arable area. In addition, climate changes have been affecting paddy irrigation water requirements during the rainy and dry seasons (De Silva *et al.* 2007). Therefore, the System of Rice Intensification (SRI) is proposed as an alternative cultivation method with more efficient input by providing suitable growing conditions in the root zone. The basic concepts are single planting with younger seedlings (7–14 days after seeding), wider spacing between transplanted seedlings, application of intermittent irrigation, organic fertilizer and very active soil aeration (Uphoff and Kassam 2008; Stoop *et al.* 2002).

Since introduced in 1999 dry season by the Agency for Agricultural Research and Development (AARD) in Indonesia, the SRI cultivation has been widespread in some areas through several programs. By adopting alternate wetting and drying irrigation (AWDI), the water use can be reduced up to 40% (Sato *et al.* 2011; Sato and Uphoff 2007). However, there were some limitations in disseminating the SRI cultivation system in Indonesia, such as irrigation management and water control (Gani *et al.* 2002).

Further investigation focusing on the water productivity by finding the optimal irrigation regime is needed. Precise data sets on rice field environment such as soil and meteorological data through continuous measurements are vital for this purpose. A demonstration study on information technology (IT) field monitoring for rice field in SRI environments in Japan has been conducted (Manzano *et al.* 2010). However, the study was limited only to the demonstration of the functionality of the IT monitoring system.

The current study aimed at establishing a new hybrid monitoring system, called field network system (FNS), to monitor paddy field's conditions under SRI environments in Indonesia with different water management regimes. Then, evaluation of water productivity was performed to compare the irrigation regimes.

2. MATERIALS AND METHODS

A field monitoring system was set up under natural environment in the Nagrak Organics SRI Center (NOSC), Sukabumi West Java, Indonesia during the first rice season 2010/2011 (October 2010 to Februari 2011, wet season). The field is located at 06°50'43" S and 106°48'20" E, at an altitude 536 m above mean sea level.

SRI cultivation practices

Each experimental plot was a 4 m x 4 m rectangular shape. All plots were planted with the local variety of rice (*Oryza sativa* L), Sintanur, a hybrid rice variety suitable for SRI. The elements of SRI practices were; single planting of young seedling (5 days after seedling) spaced at 30cm x 30cm, using an organic fertilizer at 1 kg/m^2 on the land preparation and no chemical fertilizer. Moreover, to enhance biological activity in the soils, local indigenous microorganisms (IMO) were supplied to the field 10, 20, 30 and 40 days after transplanting (DAT) accompanied with to weeding process.

Fig.1. Map showing the study area in Nagrak, Sukabumi, Indonesia.

SRI Field monitoring system

We prepared a hybrid remote monitoring system, called field network system (FNS), having a field router equipped with an in situ camera and connected to meteorological and soil data loggers. Here, a Davis Vantage Pro2 Weather Station was

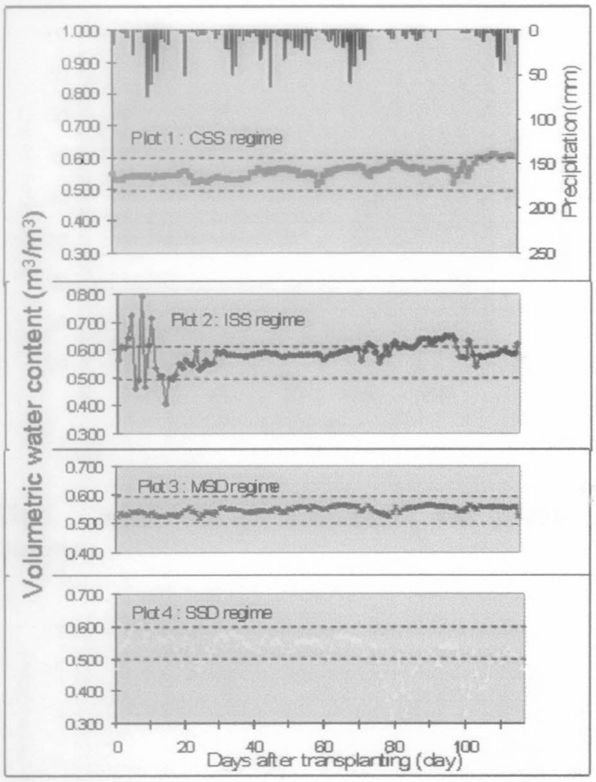

Fig.8 Soil moisture in each regime and precipitation during planting period.

In the third plot, MSD regime, soil moisture changes was between 0.500 m^3/m^3 and 0.600 m^3/m^3 in the entire planting period. The lowest and highest values were 0.521 and 0.564 m^3/m^3, respectively. The last regime, SSD regime, showed that the soil moistures fluctuated almost always in the planting season. From the early to crop development stages, the values of soil moisture ranged between 0.500 and 0.600 m^3/m^3. However, severe soil drying occurred in the reproductive and late stages when soil cracking developed at the soil moisture of 0.320 m^3/m^3.

Soil temperature trends were comparable among all plots as shown in Fig.9. The soil temperatures' trends were high until the plant age reached to 50 DAT (October-November 2010) and then decreased during December 2010 to 1 February 2011. The highest soil temperature of 35.7°C was observed on 13 November 2010 in the second regime. On the other hand, the lowest value was 22.0°C in the first and fourth plots. However, there were missing data in the fourth plot on 43 and 44 DAT (26 and 27 November 2010) since the soil sensor cable was unplugged from the soil data logger when checking the sensor. This condition was identified after data uploaded to the server.

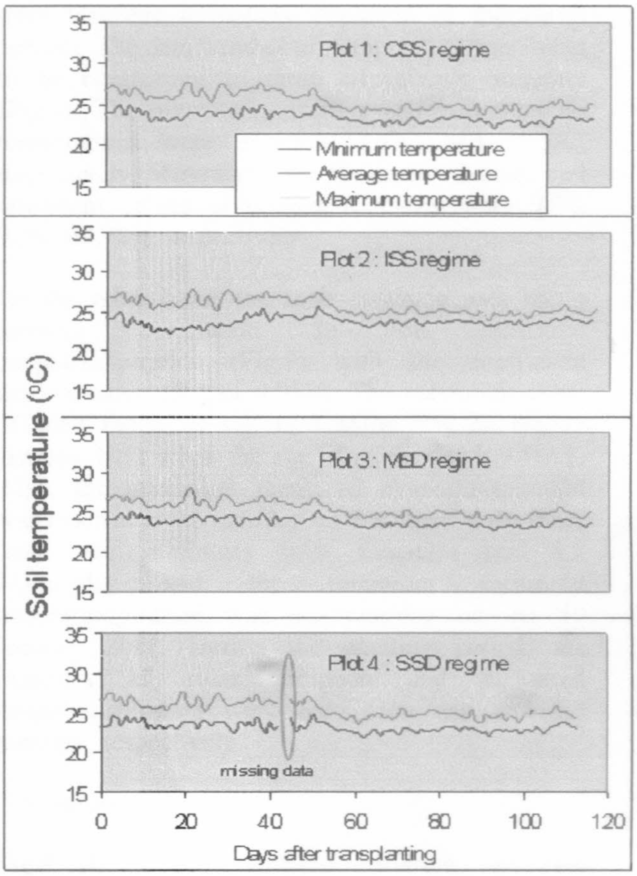

Fig.9 Soil temperatures fluctuation in all plots.

Soil electrical conductivity (EC) presents the ability of substances in the soil to conduct electricity; hence it can be used to infer the solute concentration in the soil. However, the current soil EC measurement only shows the pore water EC. To determine soil solution EC, those data should be further processed by using soil moisture data and soil bulk density (Hilhorst, 2000) and the results present in Fig.10.

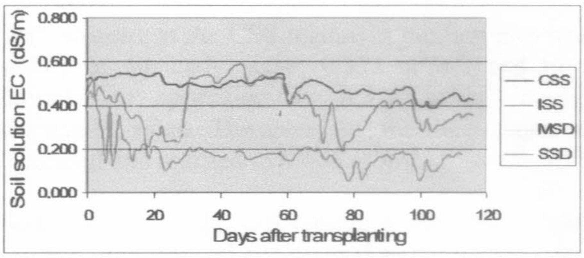

Fig.10 Soil solution EC fluctuation in all plots.

Converting soil EC values to the soil solution EC result the lower values than before. Here, we assumed the mineral density to be 2.65 Mg/m^3. From this finding, higher soil moisture results the higher soil solution EC. The SSD regime in the

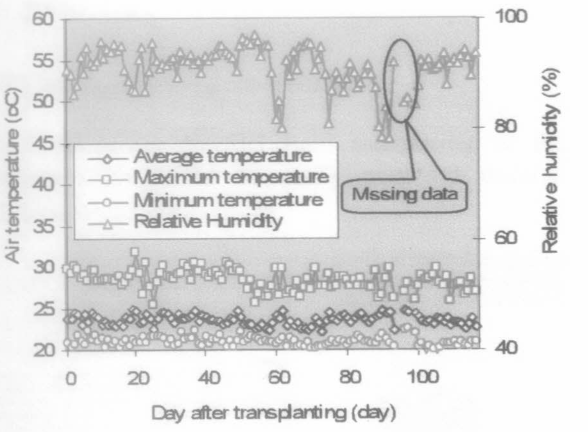

Fig.5. Changes in air temperature and relative humidity.

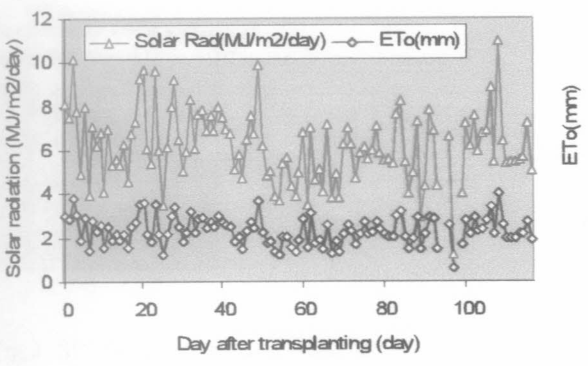

Fig.6. Daily solar radiation and measured evapotranspiration during the planting period.

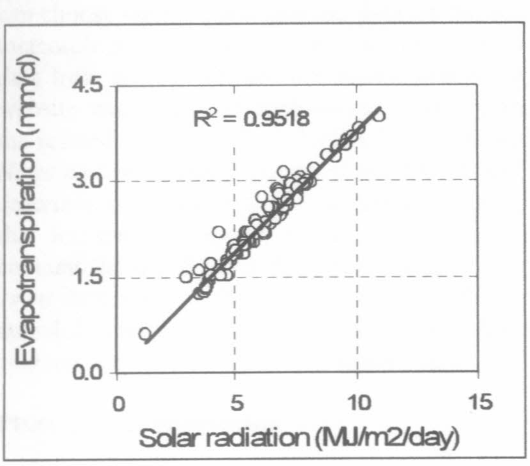

Fig.7 Regression slope between measured daily evapotranspiration and solar radiation.

The meteorological data were measured continuously and sent to the server. However, the data for 94 and 95 DAT (16 and 17 January 2011) were lost due to battery depletion of the Davis console. The data trend of air temperature was found to be contrasting to those of relative humidity (Fig.5). The maximum, average and minimum air temperatures were 31.9°C, 23.6°C, and 19.5°C, respectively. Meanwhile, the maximum, average and minimum values of relative humidity were 97%, 91% and 78%, respectively.

On the other hand, the solar radiation data had a positive correlation to the measured evapotranspiration (Fig.7) with the coefficient determination (R^2) of 0.9518. The maximum value of solar radiation was 11.0 MJ/m^2/day on the 31 January 2011 when the age of plant was 109 DAT. Also, the maximum measured evapotranspiration was reached to 4.0 mm/day on this day. On the other hand, the minimum solar radiation was 1.2 MJ/m^2/day and the minimum measured evapotranspiration was 0.6 mm/day on the 19 January 2011. During the planting period, the averages of solar radiation and measured evapotranspiration were 6.2 MJ/m^2/day and 2.3 mm/day, respectively.

Soil parameters

Fig.8 shows soil moisture variation and rain precipitation in each regime during the planting period. We observed heavy precipitation particularly in the early (0-20 DAT), crop development and reproductive stages (40-80 DAT). Heavy precipitation in the early stage resulted in great changes in soil moisture in the second and fourth plots (Fig.8). However, soil moisture levels for the first and third plots were relatively constant at this moment since the rainwater was drained rapidly. The total rain precipitation during the planting period was 1331.8 mm and the highest daily precipitation was 75.2 mm/day (24 October 2010).

Soil moisture at the CSS regime in the first plot was stabile in the early stage; 0.552 m^3/m^3, and then dropped to approximately 0.522 m^3/m^3 in the vegetative stage. However, in the late stage, it increased and reached to 0.608 m^3/m^3.

Soil moisture at the ISS regime in the second plot showed the drier soil condition than the CSS regime only in the end of the early stage at 0.405 m^3/m^3. Moreover, in the vegetative to the late stage, its value was greater than soil moisture in the first plot. From the field observation, it was difficult to keep this plot drier than the first plot due to some small holes through the bund which caused high seepage rate from the first to the second plot.

3. RESULTS

SRI information system website

All information on SRI field monitoring of the current study could be easily accessed through http://emsa-sri.org.

Fig.3. SRI field monitoring website.

We called the website as *"an Environmental Monitoring System on the Advancement of the System of Rice Intensification"* (EMSA-SRI). We can choose numeric and graphic data on the soil and meteorological parameters as well as plant image data from the *EMSA-SRI site* menu. Moreover, the website was equipped with others items related to the research such as *About EMSA-SRI, Researchers, News and event* and *Articles*. *About EMSA-SRI* item describes the concept of the current monitoring and the instruments to be used. *Researchers* item contains the list of researchers team, while *News and event* item informs the news related to SRI and the attended international conferences. *Articles* item contains articles written by the researchers.

Plant growth monitoring

Daily plant image was sent by field router through GSM network to the server. It was presented as a single image as shown in Fig.3. To see the overview of the plant images during the planting period, an image calendar was available (Fig.4). As an example in October 2010, there were 5 plant images failed being sent to the server due to the GSM network problem. However, plant images that represented each growing stage were captured and sent well to the server. In the early stage, the plant was hardly visible and the field image was dominated by soil due to a single planting with very young seedling adopted by the SRI practice. On the contrary, in the reproductive and late stages, the plants grown well to cover the entire fields (Fig.4). It was probably indicated that a single plant per hill with very young seedling promote dry matter production compared with the three plants per hill practice (San-oh *et al*, 2004).

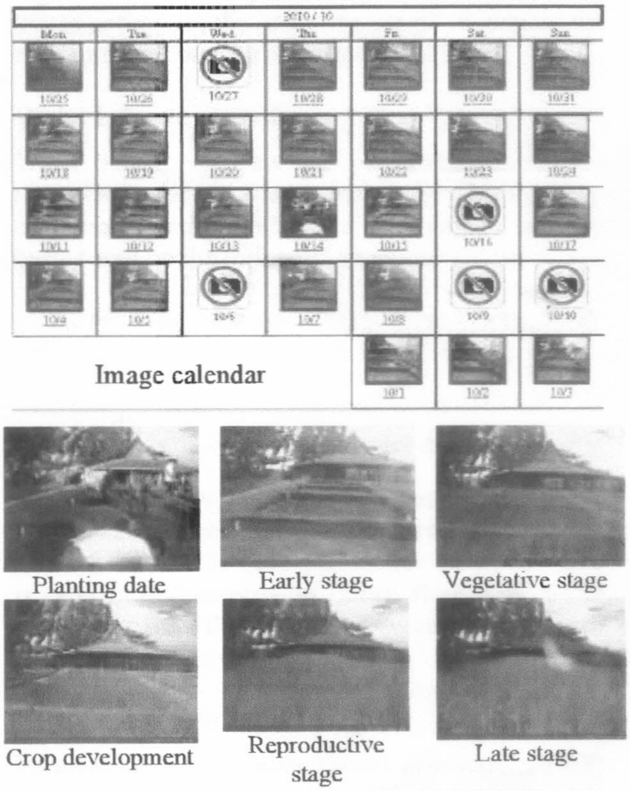

Fig.4. Plant growth was monitored by the field network system.

Dynamic changes in monitored environmental parameters

Meteorological parameters

Fig.5 and Fig.6 show the daily changes of meteorological parameters during the planting period from 14 October 2010 to 2 February 2011.

used to collect meteorological data such as solar radiation, air temperature, humidity, wind speed and direction and precipitation. Its console was connected to the field router by using Bluetooth connection. In the soil layer, soil moisture sensors (5TE: soil moisture, temperature, electrical conductivity), developed by Decagon Devices, Inc., USA, were installed at the 10-cm depths from the top of soil in each plot and then were connected to an Em50 data loggers by using cable (Fig 2).

Every sensor was set up to measure soil and meteorological parameters every 30 minutes. Then, the data were stored in each data logger. The field router was set to automatically work from 12.00 to 12.30 PM regulated by a timer to collect the data from the both data loggers, and then to send the data as well as plant image to the data server through the GSM connection. Users could easily obtain the data by accessing our SRI observation website.

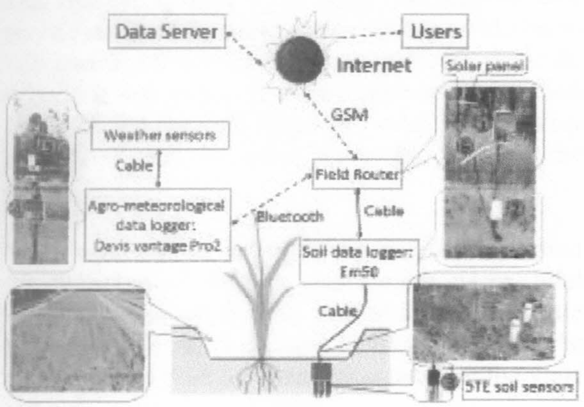

Fig.2. FNS remote monitoring in SRI paddy field.

Water management

Experimental plots were irrigated under different management regimes as enlisted in Table 1.

Table 1. Water management regimes in the fields

Irrigation regime	Water management regimes
Continuous saturated soil (CSS)	Soil was kept saturated or at water levels -5 to 0 cm depth during planting period as recommended by the SRI training center in Indonesia
Incompletely saturated soil (ISS)	Soil was kept drier than the CSS regime at water levels of -15 to -5 cm.
Moderate soil drying (MSD)	Moderate soil drying was applied at water levels of -30 to -5 cm depth
Severe soil drying (SSD)	Severe soil drying was applied at water levels -60 to -10 cm particularly from 70 day after transplanting

For the first plot, the soil was kept saturated during planting period which is called continuous saturated soil (CSS) regime as recommendation from the SRI training centre. Irrigated water was supplied to keep the soil moisture between 0.511 and 0.608 m^3/m^3. For the second plot, the soil was kept drier than the first plot and we called it as incompletely saturated soil (ISS) regime in which the minimum soil moisture value reached 0.405 m^3/m^3. For the third plot, moderate soil drying (MSD) regime was applied at the maximum soil moisture value of 0.564 m^3/m^3. The last plot, severe soil drying (SSD) regime was applied particularly from 70 days after transplanting to the maturity stage in which the minimum soil moisture reached 0.320 m^3/m^3.

Water balance analysis

Water balance analysis was performed to estimate irrigation water and water consumption through crop evapotranspiration within the crop season in daily basis based on the following equation:

$$\frac{dS}{dt} = P(t) + I(t) + Gw(t) - Qr(t) - DP(t) - ETc(t) \quad (1)$$

Where, $\frac{dS}{dt}$ is daily change in water depth (mm), P is precipitation (mm), I is irrigation water (mm), Gw is groundwater level (mm), Qr is run off/drainage water (mm), DP is deep percolation (mm) and ETc is crop evapotranspiration (mm). Here, Gw, water that comes from the ground, was assumed to be zero due to the change was negligible.

Water productivity

Furthermore, we calculated water productivity (WP) to look up another water-rice production relationship (Molden et al. 2003). In paddy fields, WP is calculated using the following equation (Van der Hoek et al. 2001):

$$WP = \frac{Y}{\sum ETc} \quad (2)$$

where, ETc is total water consumption by crop evapotranspiration (mm) derived from water balance analysis.

fourth plot had the lower values than those CSS and MSD regimes. However, soil solution EC values for the ISS regimes gave the lowest values in the early stage when the soil moisture was fluctuating, and then soil solution increased as the soil moisture increased in the next stage.

Water productivity

Table 2 presents water productivity for all irrigation regimes. From the water balance analysis, total irrigation water for ISS regime was highest among all regimes. Although this regime was drier than CSS regime for the particular moment, however, during vegetative to the last stage this regime was more saturated than CSS regime as shown in Fig. 8 which means more water input applied to this regime. Moreover, even the SSD regime was drier than the CSS and MSD regimes; the total irrigation water was higher than both CSS and MSD regimes. This was due to more water input is needed to raise the soil moisture from the extremely dry condition to saturated condition (approximately 0.300 to 0.520 m^3/m^3). It was occurred three times on 80, 85 and 101 DAT and the total irrigation water was 114 mm or 43% of total irrigation water for SSD regime (Fig.8).

Water consumption through crop evapotranspiration for all irrigation regimes was similar. Here, total water consumption for ISS and SSD regimes were higher than in the SCC and MSD regimes. There seemed have a positive correlation between the yield and water productivity (Table 2).

Table 2. Water productivity for each water management regime

Components	Irrigation regime			
	CSS	ISS	MSD	SSD
Irrigation water (mm)	144	346	115	266
Water consumption (mm)	241	265	248	260
Yield (t/ha)	4.69	5.31	3.75	5.31
Water productivity (kg/m3)	1.95	2.01	1.51	2.04

Values of water productivity for CSS, ISS and SSD regimes were 1.95, 2.01 and 2.04 kg/m^3, respectively. These values were higher than that for the intermittent system reported by Chapagain and Yamaji (2010). In addition, though the water productivity for MSD regime was lowest in the current study (1.51 kg/m^3), its value was still higher than the flooded system reported by Chapagain and Yamaji (2010).

4. GENERAL DISCUSSIONS

Daily SRI field conditions were monitored properly by the developed field router connected to the meteorological and soil data loggers. Although this monitoring didn't send real-time data, the data were stored in the field data loggers. By adopting quasi-real time monitoring, it was more power saving and Internet cost effective than the real time monitoring by using field server developed in the previous study (Manzano et al. 2010; Mizoguchi et al. 2008).

However, stability of the field router depends on the field solar power supply and the Internet connection. In case there is problem in the Internet connection within the data transmitting time, the plant images data were lost as shown in Fig.4. Moreover, data were also lost when the data logger battery is depleted or the sensor cable is unplugged as shown in Fig. 5 and Fig.9, respectively.

The images showed the SRI plant growth from the single seedling to the harvesting time when large areas were covered. In this monitoring, it was relatively easy to determine each plant growth stage and then evaluate the water management regimes based on the field conditions.

In addition, the numeric data showed the reasonable values for both the meteorological and the soil parameters. With these precise data, evaluation of water productivity for the 4 irrigation regimes could be easily analyzed. In fact, the soil condition in ISS regime was almost always more saturated than CSS regime in the planting period. However, the more saturated soil condition in the early to the crop development stages for the ISS and SSD regimes could increase the yield and the water productivity (Table 2).

5. CONCLUSION

The developed Field Network System (FNS) was effective, efficient and reliable in monitoring SRI paddy fields in Indonesia. The actual field conditions were monitored well in term of image, numeric and graphic data acquisition. With these data, plant growth and water management can be more easily monitored and evaluated. The current findings revealed that in the early to the crop development stages, the soil should be more saturated to gain more yield and water productivity as seen in the current cases of the incompletely saturated soil (ISS) and the severe soil drying (SSD) regimes.

ACKNOWLEDGEMENT

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