Dynamic Design of Water Flow Management in Lebak Swamp Land, Pesisir Selatan District, West Sumatra During the Covid-19 Period

Yenita and Agustinus Purna Irawan
Faculty of Engineering
Universitas Tarumanagara
Letjen S. Parman No. 1, West Jakarta, Indonesia
yenita@fe.untar.ac.id

Abstract

Pesisir Selatan District is located on the coast, with a coastline of 218 kilometers. The topography consists of plains, mountains and hills. The expansion of agricultural areas in Pesisir Selatan District has an important meaning given the limited land for agricultural cultivation in the area. The water level will fluctuate due to the influence of the season and rainfall, where during the rainy season the soil is flooded and during the dry season it will recede, so that plant commodities to be developed must pay attention to their adaptability to groundwater depth. This research aims to support government programs in reclamation of agricultural land in an effort to maximize the function of lebak swamplands. Primary data includes groundwater and water in canals, temperature, soil physical properties, and rainfall. The analysis used is an analysis of the relationship between rainfall, temperature, soil physical properties, and the water level in the canal to fluctuations in the groundwater level. The results of the analysis show that temperature, rainfall, soil conductivity, and the rise and fall of the water level in the canal have an effect on the rise and fall of the groundwater level. Dynamic model in water management can be used as a guideline for the use of lebak swamp land during the Covid-19 pandemic. The potential for utilizing lebak swamp land as an alternative for future land through the concept of optimizing land resources is carried out with an integrated farming system that is environmentally friendly.

Keywords
Design, Waterflow, Lebak, Swampland, West-Sumatra

1. Introduction

Wetlands in Indonesia have an important role where the prospect of expanding irrigated land will lead to natural wetlands, especially swamplands, both tidal swamps and lowland swamps (Adimihardja, 2017). Swamp is a natural pool of water that occurs continuously or seasonally due to blockage of natural drainage and has special physical, chemical and biological properties (Nursyamsi, 2014). Swamps in Indonesia are mostly located in Sumatra, Kalimantan and Papua. Lebak swamp land is an alternative land that can be used for agriculture. The use of lebak swamp land is a strategy, given the narrowing of agricultural land due to the conversion of paddy fields and the increasing demand for food and other agricultural products due to the growing population (Balitbangtan, 2014).

Swamp Lebak is an inland swamp whose topography is relatively concave and water cannot flow out (Alihamsyah, 2014). This land experiences inundation every year for at least three months with a minimum inundation height of 50 cm (Masganti, *et.al.,*2013). During the rainy season the ground is flooded and recedes during the dry season. Therefore, lebak swamps are depression areas where the main source of water comes from rainfall and tides during the dry season (Subagjo, 2006). According to Government Regulation Number 73 of 2013 concerning Swamps, in Article 5 paragraph 2 what is meant by lebak swamps are swamps that are located far from the coast and are inundated due to overflowing river water or rainwater that stagnates periodically or continuously.

Pesisir Selatan District is located on the coast, with a coastline of 218 kilometers. Its topography consists of plateaus, mountains, and hills. The majority of swamps in Pesisir Selatan district are idle lands because almost all of them are overgrown with swamp grass and shrubs. The expansion of agricultural areas in lebak swamps in West Sumatra has a very important meaning given the limited land for agricultural cultivation in this area. Most of these swamps are formed on the Pesisir Selatan of West Sumatra with physiographic conditions consisting of allivual plains, peatlands, and volcanic plains which are found in several locations in Pesisir Selatan District.

In lowland swamps, plants will grow and develop well if the depth of the water table matches the plant root zone, and the pyrite in the soil is not oxidized. The groundwater table will fluctuate due to the influence of rainfall so that the selection of plant commodities to be developed in lowland swamps must pay attention to the adaptability of a plant to the depth of the groundwater table in the land.

According to Subagyo (2006), the morphological characteristics of the soil in lebak swamps indicate that these soils have not yet developed, especially in areas with limited to severely obstructed drainage. Apart from hydrological problems, another biophysical problem in developing lowlands for food production is the relatively low and varied soil fertility (Noor, 2007). Diversity of soil fertility in lowland areas depends on soil typology and soil type. Shallow swamps generally have better soil fertility due to the enrichment of silt brought by overflowing river water (Mukhlis, et. al., 2014).

In general, the fertility level of lebak swamps is better than tidal swamps, because the soil in lebak swamps is composed of river sediments (fluviatile) which do not contain sulfidic or pyrite materials. Lebak swamp land is one of the sub-optimal lands that can be utilized for the development of various commodities, both food crops, horticulture, plantations, fisheries, and livestock. Shallow swamps are the most potential part for agriculture compared to middle and deep swamps. Shallow and middle lebak swamps are usually used as paddy fields by planting crops and vegetables in the mounds/beds in the surjan system. Meanwhile, deep valleys, because they are shaped like basins, the water conditions are still relatively deep, even during the dry season, so they are more suitable for freshwater aquaculture. The main obstacle in the management of lebak swampland is the water level during the rainy season and vice versa during the dry season the waterlogging does not decrease to almost dry.

1.1 Objectives

In lebak swamps land, plants will grow and develop well if the depth of the groundwater table matches the plant root zone, and the groundwater level will fluctuate due to the influence of rainfall, so the selection of plant commodities to be developed must pay attention to the adaptability of plants to the depth of the groundwater. Therefore, the purpose of this study was to examine the dynamics of groundwater flow fluctuations in the lebak swamplands in an effort to maximize the function of the lebak swamps during the Covid-19 pandemic in Pesisir Selatan District, West Sumatra.

2. Literature Review

2.1 Swamp Land

Swamps are land that is inundated periodically or continuously naturally for a long time due to blocked drainage. Although in a state of flooding, this land is still growing plants. This land can be distinguished from lakes because lakes are flooded all year round, the vegetation is deeper, and there is no vegetation except aquatic plants (Mitsch & Gosselink, 2015). Swamp inundation can be caused by rising sea water, rainwater stagnation, or river overflow. Based on the causes of inundation, swamps are divided into three, namely tidal swamps, low swamps, and transitional low swamps (Noor, 2017).

2.2 Lebak Swamp Land

Swamp Lebak is a swamp where inundation occurs due to overflow of river water and/or rainwater in a basin area towards the mainland (Noor, 2017). In other words, lebak swamps can be formed by rainwater or river floods, so they are often found on either side of rivers inland. Thus, this swamp expands in the rainy season and gradually shrinks, it may even dry up during the dry season (Suriadikarta, 2012). Lebak swamp can be divided into three types (Soebagjo, 2006), namely:

a) Shallow swamp or bund swamp, which is a swamp with stagnant water less than 50 centimeters. These lands are usually located along river embankments with an inundation period of less than 3 months;

b) Middle Lebak Swamp, which is a valley with a pool of water as deep as 50-100 centimeters. Inundation usually occurs for 3-6 months.

c) Deep lowland swamps, namely valleys with standing water of more than 100 centimeters. This land is usually located on the inside far from the river with a long inundation of more than 6 months.

2.4 Groundwater

Groundwater according to Soemarto (1999) is water that occupies cavities in geological layers. The layer of soil that is below the groundwater table is called the saturated zone, and the unsaturated area is located above the saturated area down to the ground surface, where the voids are filled with water and air. Groundwater is found in permeable geological formations known as aquifers which are water-binding formations that allow appreciable amounts of water to move through them under ordinary field conditions. Groundwater is also found in acyclic (or semi-permeable bottoms) which contain water but cannot displace water in significant amounts such as clay (Seyhan, 1993).

2.5 Groundwater Movement

The general equation for groundwater flow can be found based on Darcy's law and the continuity equation (Figure 1) (Soemarto, 1999).

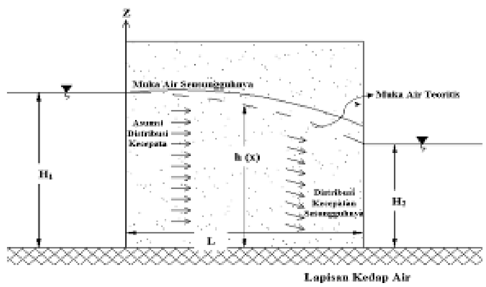

Figure 1. Flow through the embankment without rain (Bisri, 1991)

For free aquifers with rain, it can be explained by the following Figure 2:

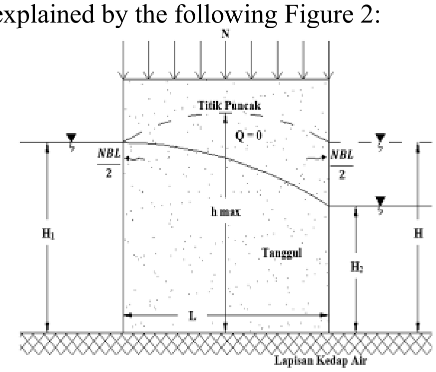

Figure 2. Flow through the embankment with rain (Bisri, 1991)

2.6 Soil Physical Properties

Soil has physical, chemical and biological properties that characterize it. Soil characteristics can be used to determine the type of soil. Soil physical properties include: (Kodoatie, 2012)

1. Hydraulic Conductivity

Hydraulic conductivity is a parameter that indicates the soil's ability to pass through a certain amount of water.

2. Moisture Content

Moisture content is defined as the ratio between the water content and the total soil material content, while the gravimetric water content is defined as the ratio of the weight of water to the total weight of soil material.

3. Porosity

Porosity is defined as the ratio of the void content divided by the total soil matter content. The amount of porosity for several types of soil (Kodoatie, 2012):

a. Gravel → porosity ranges from 25 – 40%
b. Sand → porosity ranges from 25 – 50%
c. Silt → porosity ranges from 35 – 50%
d. Clay → porosity ranges from 40 – 75%

4. Soil Fill Weight

The bulk density of the soil is the ratio between the weight of the soil and the volume of the soil.

5. Soil Specific Gravity

© IEOM Society International

The specific gravity of soil is defined as the ratio between the unit weight of solid particles (γs) and the volume weight of air (γw) at 4^0C.

3. Methods

This research is an observational study using primary data based on field observations during the Covid-19 period. The research was conducted in Pesisir Selatan District, West Sumatra. The research time needed to collect data is 15 days. The analytical method used for groundwater level fluctuations uses groundwater adjustment modeling based on Darcy's law and the continuity equation. The modeling carried out is modeling on one-way water flow conditions and on free aquifers (Figure 3).

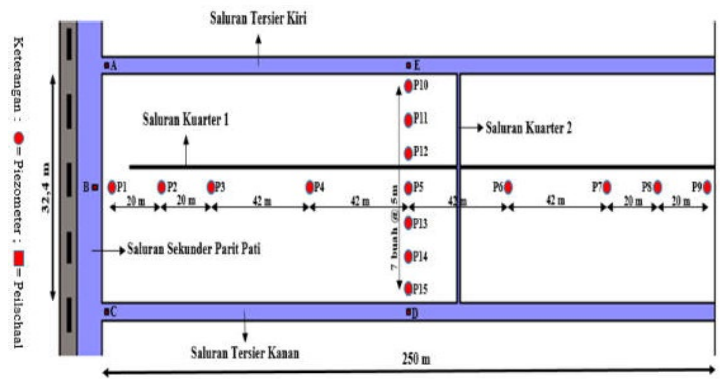

Figure 3. Layout of groundwater level & water channel observation points

4. Data Collection

Primary data is data obtained directly by measuring and observing in the field. The primary data used comes from:

a) Temperature data

Temperature measurements were carried out for 15 days with an interval of 1 hour.

b) Groundwater table data

Observation of the groundwater level was carried out by making observation wells made of PVC pipes with a diameter of 2.5 inches and a length of ± 2 m. Groundwater level observations were carried out for 15 days with an interval of 1 hour.

c) Rainfall Data

Rainfall data was measured for 15 days with 1 hour intervals. using a manual rain gauge.

d) High-end airway data

The water level in the channel is measured using a measuring tape (peilschaal). Observation of water level in the channel was carried out for 15 days with an interval of 1 hour.

e) Soil physical properties data

Soil physical properties data obtained from the results of testing several soil samples in the laboratory. Parameters tested were water content, hydraulic conductivity and porosity.

While the secondary data used is data obtained from other sources or through second party intermediaries or from related agencies, namely data that has been compiled in the form of documents or can also be in the form of reports on the results of research conducted by other parties.

5. Results and Discussion

5.1 Results

A. Rainfall

Rainfall data is obtained from direct measurements in the field using a manual rainfall gauge. The tool is placed in a large area or not covered by anything that can interfere with the entry of rainwater into the rain gauge (Figure 4). The maximum rainfall that occurs is 258 mm/day.

© IEOM Society International

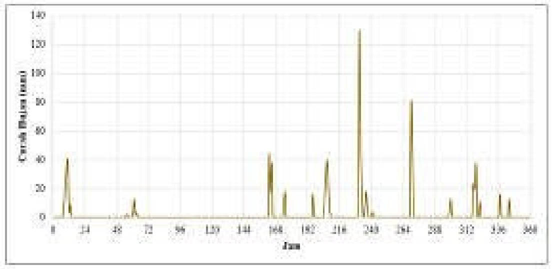

Figure 4. Rainfall for 15 days

B. Temperature

To collect temperature data, measurements were made directly in the field using a room thermometer placed at the study site. The temperature at the study site ranges from 26^{0}C – 35^{0}C (Figure 5).

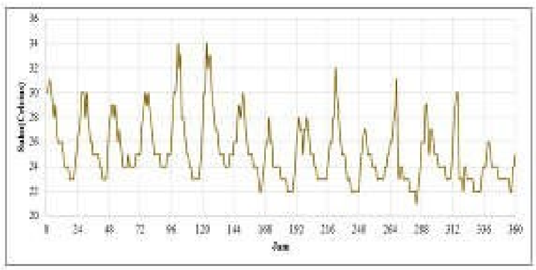

Figure 5. Temperature for 15 days

C. Soil Physical Properties

Soil sampling was carried out using a cylindrical ring that has the same diameter and height of 5 cm. Soil sampling was carried out at a depth of more than 30 cm from the soil surface. Based on the results of sample data collection in the field, the porosity values for the soil types in this study ranged from 66.8 - 75.5%. The soil porosity value indicates that the soil in this location can be classified into the type of clay, where according to Kodoatie (1996) this type of clay has a porosity value ranging from 40 – 75%, which means it is very good for agricultural land use.

D. Relationship Between Groundwater and Canal Water Tables

The measurement results show that there is a relationship between the groundwater level and the water level in the canal. This can be seen from the fluctuations that occur (Figure 6). Based on the figure, it can be seen that the fluctuation of the groundwater level at each point has a similar pattern to the fluctuation of the water level in the canal, meaning that when the water level in the canal rises, the groundwater level at each observation point will also rise, and vice versa. So it can be said that the relationship between the water level in the canal and the groundwater table is linear.

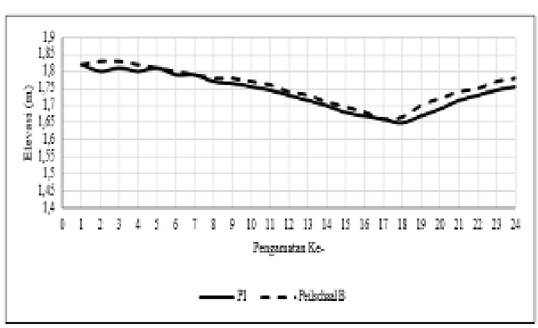

Figure 6. Groundwater and canal water level fluctuations

E. The Effect of Rain on the Groundwater Table

The effect of rain on the groundwater table can be seen from changes in the average hourly groundwater level, where on the 7th day there was moderate intensity rain and on the 14th day there was no rain. The observation results show that changes or fluctuations in the groundwater level during rains are greater than when it is not raining. The physical properties of the soil such as the conductivity of the soil is one of the factors causing this to happen. So it can be said that rain has a significant influence on the fluctuations that occur in the groundwater table. Besides affecting fluctuations in the groundwater level, rain also causes the water level in the canals to rise. The greater the rainfall that occurs, the greater the rise in the water level in the channel. In addition, the rain also caused puddles at several observation points some time after the rain. The points that experience inundation are points that have a relatively low altitude, where inundation occurs due to rain.

F. Relationship of Soil Conductivity and Groundwater

Hydraulic conductivity has a relationship with fluctuations in the height of the water level in the soil, where hydraulic conductivity is a parameter or measure that can describe the ability of the soil to pass air (Mukhlis, et.al. 2014). The relationship between the conductivity value of the soil and the fluctuations in the water level that occur in the soil based on observations shows that in areas that have high soil conductivity, the contour lines of the groundwater level or fluctuations in the groundwater level that occur in that area are also large or fast, and vice versa. So it can be concluded that the relationship between fluctuations in the groundwater level and the conductivity value of a soil is linear, that is, the greater the conductivity value of a soil causes the groundwater level to rise, and vice versa.

G. Application of Models

The model used to estimate groundwater levels in the field is based on Darcy's law and the law of continuity. In modeling, the reference points must be at the same level, where for transverse conditions the bottom elevation of the left tertiary canal is used as the reference point and the basic elevation of the starch ditch is used as the reference point for the longitudinal modeling direction. The N and K values that are suitable for use in modeling when it rains are N values of 0.25 mm/day and K of 0.45 m/hour (Figure 7).

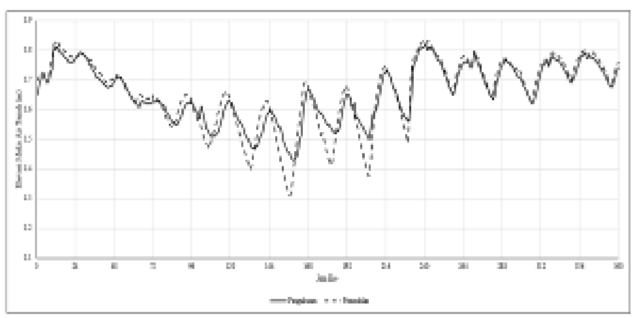

Figure 7. Graph of predicted fluctuations in the groundwater level

Based on the model testing carried out, it shows that the model has been able to predict the groundwater level at the research location with good results, this is indicated by the coefficient of determination (R2) of 87,8%. Then by using a model that has been tested for reliability, it is possible to make adjustments to the water management system in the tertiary channel for controlling the groundwater level in the lebak swamp land plots (Figure 8). The following water management arrangements can be used as guidelines in the implementation of water management according to plant commodities to be developed in lebak swamplands. The planned depth of the right and left tertiary canals is 2 meters from the average ground surface and it is assumed that the water levels of the right and left tertiary canals are the same.

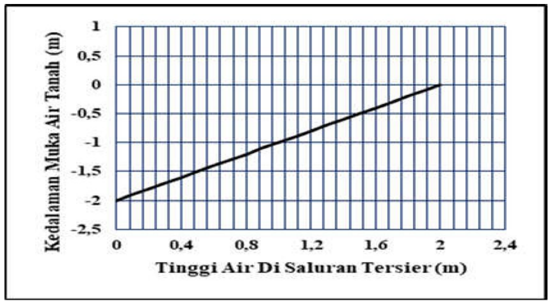

Figure 8. Graph of water management in tertiary canals

Setting the water level in the tertiary canal can be done by constructing a water control structure in the form of a sluice gate. When there is no rain, the water level in the ground will also decrease. Under these conditions it is necessary to carry out water retention in order to maintain the groundwater table at a certain depth. Sluice gates are also used when you want to do drainage when excess water occurs after heavy rains to maintain the groundwater table at a certain depth.

5.2 Discussion

Lebak swampland has a competitive advantage compared to other types of land. One of the potentials of lebak swamp land is its use as agricultural land, such as rice, secondary crops, and horticulture. Cropping patterns and types of commodities that can be developed in swamps are very dependent on land typology. The details of the lebak swamp typology and its potential are as follows:

a) Lebak bund swamp (shallow). This lebak swamp land can be utilized for the development of food crops and horticulture (vegetables) in monoculture or intercropping. For the use of lebak swamp land as rice fields, it can be planted in the dry season and also in the rainy season. During the dry season it is called the eastern rice fields, the rice fields are planted with short-lived rice. Palawija, vegetables and fruits are also widely grown in the swamps with an intercropping pattern with the surjan system. In the surjan system, crops, fruits and vegetables are grown on high parts (mounds). Rice is grown in waterlogged areas. In the dry season, the shallow valley becomes dry so it is planted with vegetables, crops and fruits. The fruit planted in this hole is a type of annual fruit such as watermelon or melon.

b) Swamp lebak central lowlands. This lebak swamp land can be utilized for the development of food crops and horticulture (vegetables) in monoculture or intercropping. The cropping pattern that can be applied in this lebak swamp is lowland rice or rice and horticulture. During the rainy season, the central part of the Lebak swamp is inundated by more than 100 cm of water, so it is called the western part of the rice field.

c) Deep low swamps. The use of lebak swamps depends on the height of the groundwater table, if it is still possible to cultivate food crops in wetlands then the land can be used for the development of rice, both plain rice and lebak rice, but if this is not possible, then the lebak swamps will function as a water conservation area.

The lebak swampland has a special advantage, namely that it can be cultivated as agricultural land during the season when other agro-ecosystems (irrigated rice fields and rainfed rice fields) experience drought so that agricultural products can be sold at high prices. The most notable competitive advantage of the swamps is that most of the rice harvest is carried out in the dry season months elsewhere. Therefore, lebak swamps function as production buffers in national food security (Suryana and Yasin, 2017).

Water management in the lowland and middle valleys can be developed by building canals in plots of land that also function as fish shelters or natural fish nurseries, as well as water reservoirs for crop needs during the dry season. During the Covid 19 period, farmers cultivated this land with various types of plants, ranging from annual crops, especially food crops, horticultural crops, industrial crops, or combined with fishery or livestock commodities. For food crops, rice is the dominant commodity cultivated in the lowlands of lebak during the Covid-19 pandemic.

5.3 Proposed Improvements

The depth of the groundwater table can be predicted through the model parameters that have been used and the depth of the groundwater table can be controlled at a certain depth by adjusting the water level in the tertiary channel. In its implementation, so that groundwater conditions can increase plant production in lebak swamp land,

© IEOM Society International

it is necessary to make guidelines or guidelines regarding the operation of floodgates in tertiary canals. Further research on water control building system engineering in tertiary canals can improve the models and techniques that have been developed in this study.
It is necessary to reaffirm the potential and opportunities for utilizing lebak swamp land as an alternative land for the future. It is necessary to build public awareness of the importance of developing lebak swamplands in a sustainable manner. Optimization of land resources is carried out with an appropriate, innovative, integrated and sustainable system with the concept of an environmentally friendly integrated farming system.

6. Conclusion

The expansion of agricultural areas in Pesisir Selatan District has an important meaning given the limited land for agricultural cultivation in the area. The alternative to lebak swamp land is a solution for future agricultural land in Pesisir Selatan District. The temperature at the study site ranges from 26^0C – 35^0C, with a maximum rainfall of 258 mm/day. The soil in the research location is a type of clay which means it is very good for agricultural land. Rainfall and temperature affect fluctuations in the groundwater table. Groundwater level fluctuations are affected by hydraulic conductivity and water level fluctuations in canals. The relationship between the rise in the water level in the canals and the rise in the groundwater level is linear, where if the water level in the canals rises, the groundwater level will also rise and vice versa. The modeling simulation results show that the model can predict well the depth of the groundwater table at the study site with an average value of the coefficient of determination of 87.8%, and groundwater level control can be done by adjusting the water level in the tertiary channel.

The approach taken in the development of lebak swamp land refers to land typologies, where each land typology requires different management methods. Dynamic water flow management is the key to the successful use of lebak swamp land for agriculture during the Covid-19 period. The potential and opportunities for utilizing lebak swamp land need to be developed as an alternative for future agricultural land. Optimization of lebak swamp land resources is carried out with an innovative, integrated, agribusiness and sustainable system through the concept of an environmentally friendly integrated farming system.

References

Adimihardja, *et. al*.,*Sumberdaya Lahan Indonesia dan Pengelolaannya*. Bogor: Puslittanak, 2017.
Alihamsyah, T., *Potensi Dan Pendayagunaan Lahan Rawa Dalam Rangka Peningkatan Produksi Padi*. Jakarta: Badan Litbang Pertanian, 2014.
Badan Penelitian dan Pengembangan Pertanian., *Buku Pedoman Pengelolaan Lahan Rawa Lebak Untuk Pertanian Berkelanjutan*. Jakarta: IAARD Press, 2014.
Bisri, M., *Aliran Air Tanah*. Malang: UPT Penerbitan Fakultas Teknik Unversitas Brawijaya, 1991.
Kodoatie, Robert J., *Tata Ruang Air Tanah*. Yogyakarta: Andi, 2012.
Masganti, *Agroekologi Rawa*. Jakarta: IAARD Press, 2013.
Mitsch, W.J. & J.G. Gosselink., *Wetlands*. Hoboken, NJ: John Wiley & Sons Inc., 2015.
Mukhlis, *et. al*., *Biodiversiti Rawa*: *Eksplorasi, Penelitian dan Pelestariannya*. Jakarta: IIARD Press, 2014.
Noor, M., *Rawa Lebak: Ekologi, Pemanfaatan, dan Pengembangannya*. Jakarta: Raja Grafindo Persada, 2017.
Nursyamsi, D., M., *et.al*., *Buku Pedoman Pengelolaan Lahan Rawa Lebak untuk Pertanian Berkelanjutan*. Jakarta: Balitbangtan - IAARD Press, 2014.
Republik Indonesia. , Peraturan Pemerintah Nomor 73 Tahun 2013 Tentang Rawa , 2013.
Republik Indonesia., Peraturan Menteri Pekerjaan Umum dan Perumahan Rakyat Nomor 29/PRT/M/2015 Tentang Rawa. Jakarta: Sekretariat Negara, 2015.
Subagjo, H., *Klasifikasi dan Penyebaran Lahan Rawa*. Bogor: Balitbang Pertanian, 2006
Suriadikarta, D.A.,Teknologi Pengelolaan Rawa Berkelanjutan. *Jurnal Sumberdaya Lahan*, Vol. 6 (1), p. 45-54, 2012..
Seyhan, Ersin.,*Dasar-Dasar Hidrologi*. Yogyakarta: Gadjah Mada University Press, 1993.
Soemarto, C.D., *Hidrologi Teknik*. Jakarta: Erlangga, 1999.
Suryana & Yasin, M., *Rawa dan Pelestariannya*. Bogor: Balitbang Pertanian, 2017.

Biographies

Yenita is a graduate of the MBA program from the University of Western Australia. Currently Yenita is pursuing her doctoral degree in civil engineering at Universitas Tarumanagara Jakarta. Yenita is also a lecturer at Faculty of Economics and Business, Universitas Tarumanagara since 2004. Several fields of study taught by Yenita to date include Operations Research, Financial and Operational Management, Feasibility Studies, Quality Management,

© IEOM Society International

Supply Chain, Project Management, Service Operations, Statistics, Macro and Micro Economics, Investment and Portfolio, Mergers and Acquisitions, Managerial Economics, Strategic Management, Strategy and Corporate Restructuring. Yenita has published several journals and conference papers related to the scientific fields of engineering, management, and business.

Agustinus Purna Irawan was born in Mataram - Musirawas, South Sumatra, August 28, 1971. Is a Lecturer at Universitas Tarumanagara and has served as Chancellor since 2016 until now. Obtained a Bachelor of Mechanical Engineering from the Faculty of Engineering, Gadjah Mada University (1995), a Masters in Mechanical Engineering from the Faculty of Engineering, University of Indonesia (2003), a Doctor of Mechanical Engineering from the Faculty of Engineering, University of Indonesia (2011), Professional Engineer (Ir) Mechanical Engineering from the Faculty of Engineering, Gadjah Mada University (2019) and Professor of Mechanical Engineering from the Ministry of Education and Culture (2014). The fields of scientific research and publication include: Product Design and Development, Strength of Materials, Natural Fiber Composites with implementation in the field of prosthesis and automotive components. Obtaining Research and Community Service Grants for Higher Education / Research and Technology BRIN / Untar / Others ≥ 100 titles; Patents: 7 and still in process: 4; Copyright: 9 books; Textbooks: 6 books; Book Chapter: 2 chapters; Scientific articles ≥ 100 titles. Obtained a Professional Certificate, namely the Educator Certificate, the Intermediate Professional Engineer Certificate (IPM) of the Indonesian Engineers Association (BKM PII) Vocational Engineer Association (BKM PII), and the ASEAN Engineer Certificate (ASEAN Eng.) From the ASEAN Federation Engineering Organizations (AFEO). He is active in education, various scientific activities, the world of business, professional associations, and various social activities. Received several awards: Best Graduate S2 UI GPA 4.00 cum laude (2003); First best Lecturer Kopertis Region III DKI Jakarta (2011); Best Presentation at the Seminar on Research Results of the Centralized Program, PUPT Dikti (2014); Honorary Member of The ASEAN Federation of Engineering Organizations, AFEO (2018); Best PTS Chancellor for the Academic Leader Award Program (2019).

© IEOM Society International