



PAPER • OPEN ACCESS

## The Monsoon Pattern Analyses on the Irrigation Water Balance

To cite this article: R P Jaya *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **752** 012043

View the [article online](#) for updates and enhancements.

You may also like

- [The Operation Management Model of Intermittent Irrigation in Cihea Irrigation Area In Cianjur Regency](#)  
D Yanti, T Mandang, M Y J Purwanto *et al.*
- [Cropping pattern and schedule using K-Factor for optimizing irrigation networks operation in Krueng Jreu Irrigation Area, Aceh, Indonesia](#)  
Syahrul, M Yasar and R Safira
- [The simulation of cropping pattern to improve the performance of irrigation network in Cau irrigation area](#)  
Retno Wahyuningsih, RR Rintis Hadiani and Sobriyah

**ECS** The Electrochemical Society  
Advancing solid state & electrochemical science & technology

**247th ECS Meeting**  
Montréal, Canada  
May 18-22, 2025  
*Palais des Congrès de Montréal*

**Showcase your science!**

**Abstracts  
due  
December  
6th**

# Monsoon Pattern Analyses on the Irrigation Water Balance

**R P Jaya<sup>1\*</sup>, H G Mawandha<sup>2\*</sup>, E Mulyandari, L M Kesuma**

<sup>1</sup>Department of Civil Engineering, Universitas Janabadra, Yogyakarta, Indonesia.

<sup>2</sup>Department of Agricultural Engineering and Biosystem, Universitas Gadjah Mada, Yogyakarta, Indonesia.

<sup>3</sup>Departemen of Civil Engineering, Universitas Tunas Pembangunan, Surakarta, Indonesia.

<sup>4</sup>Study Program of Engineering Profession, Universitas Gadjah Mada, Yogyakarta, Indonesia.

\*Email: rputrajaya@janabadra.ac.id / hanggar.g.m@ugm.ac.id

**Abstract.** The water balance for irrigation is affected by conditional monsoon patterns, including the beginning of the season and the duration. In a technical irrigation service, the actual dynamic of monsoon patterns may influence the crop pattern schedule and the standard operating rule of irrigation intake. Some significant impacts on the water balance characteristics can enlarge the water deficit during drought periods and reduce the efficiency of crop intensity. Its significance can be detected by conducting hydrological simulations of water availability and water demand in certain seasonal periods. Hence, the updated crop pattern schedule and the standard operating rule of irrigation intake can be adjusted correspondingly. Moreover, the social conflict during the water distribution can be diminished, and water efficiency can be increased as well as the crop intensity. This study is conducted at Tibu Kuning irrigation area, West Lombok Regency, West Nusa Tenggara Province using 15 daily rainfall data for 25-year from 1993 to 2017. The results show that the monsoon shift pattern in the study area has an interval of 3-year with the maximum shifting period is about one month. Moreover, the monsoon shift pattern has affected the reliability of irrigation water services. In this situation, an adaptive crop pattern schedule needs to be updated to maintain agricultural productivities. Based on the results obtained in this study, updating of the crop pattern schedule and the standard operating rule of irrigation intake can be adjusted for the upcoming periods.

**Keywords.** crop pattern, irrigation, monsoon, standard operating rule, water balance.

## 1. Introduction

The characteristics of the monsoon in a particular region are strongly influenced by factors such as geographical position, elevation, ocean current, land cover, and topographical conditions [1]. The Indonesian monsoon is a part of the East and Southeast Asian monsoon. In the southern hemisphere Indonesia, such as southern Sumatera, Java, Bali, Lombok, Nusa Tenggara up to Papua, the boreal winter monsoon is affected by the west monsoon. While over northern hemisphere Indonesia, such as northern Sumatera and West Kalimantan, the monsoon wind comes from the northeast direction called northeast monsoon [2]. Indonesia, as a large population and growing agriculture sector, which depends on monsoon rainfall patterns, it is vital to explore the response of monsoon



dynamics [3].

In the case of agricultural activities, the monsoon shift pattern has caused poor irrigation services to be fulfilled. It because farmers and irrigation operators often overlook the necessity to adjust the crop schedule due to lack of supporting decision information [4-5]. Currently, the standard operating rule used for reservoir or irrigation intake is only determined based on the beginning of the monsoon periods and the prediction of the total amount of precipitation provided by Meteorology, Climatology, and Geophysical Agency. However, that information may be insufficient when the irrigation operators consider how much water needs to release, while farmers need to know the realization of the planting area correspondingly. This situation has often triggered a conflict of interest. Also, it contributes to a decrease the irrigation efficiency in primary irrigation systems in Indonesia.

The analysis of the monsoon shift pattern is conducted based on the conditions of water availability (seasonal inflow). This seasonal inflow is generated based on the relationships between effective rainfall, soil factors, and the evapotranspiration rate, which are an important component for water balance analyses [6]. This study aims to provide an overview of the monsoon pattern based on the seasonal inflow for 20-year, to improve the performance of irrigation water services to be more efficient. The case study was taken from the Tibu Kuning irrigation service area in West Lombok Regency, West Nusa Tenggara Province, Indonesia. This area is located in the central part of the Indonesian archipelago, with the seasonal monsoon is mainly dominated by ocean current and characterized by anisotropic rainfall conditions.

## 2. Materials and Methods

This research was conducted by utilizing rain data records obtained from Kuripan Station (1993-2006) based on automatic rainfall recorder type and TRMM satellite data (2007-2017). The climatological data were obtained from the Kediri Station operated by Meteorology, Climatology, and Geophysical Agency. The analysis of irrigation water balance was carried out by comparing the inflow and outflow volumes from the Tibu Kuning reservoir. The Tibu Kuning reservoir has 23 hectares inundation area, with 1.25 million m<sup>3</sup> effective storage, and the catchment area is 9.5 km<sup>2</sup>. This reservoir serves an irrigation area of 266 hectares, with a yearly cropping pattern consists of three cycles, including Paddy, Paddy-Corn, and Corn, with a cropping schedule starts on October-November [7].

In this study, the monsoon shift pattern was analyzed based on the reservoir inflow characteristics for 20-year (1993-2012) and validated using the upcoming 5-year data (2013-2017). The analysis was carried out using the phase correlation model to identify the lag time for each annual inflow data series. In this case, the lag time value is determined based on the maximum correlation value ( $C_{max}$ ) [8- 9]. A lag-time value greater than zero indicates a shift in the monsoon pattern. In general, the formula used in the phase correlation analysis model can be described as follows.

$$\Delta x = \frac{C(1,0)*xp + C(0,0)*x}{C(1,0) + C(0,0)} - 1 \quad (1)$$

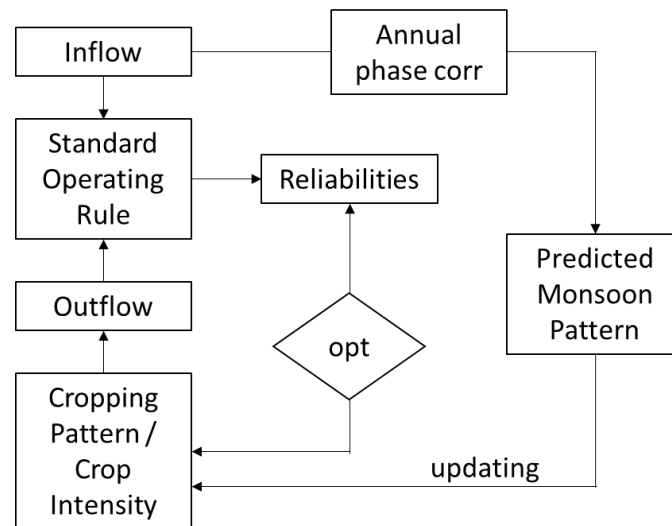
$$\Delta y = \frac{C(0,1)*yp + C(0,0)*y}{C(0,1) + C(0,0)} - 1 \quad (2)$$

where  $C(0,0)$  is the correlation at the central peak, while  $C(1,0)$  and  $C(0,1)$  are the neighbors with the largest value in both horizontal and vertical directions, respectively. In this case, the horizontal axes represent the time-shifting, and the vertical axes represent the inflow rates. Where  $xp$  is positive  $x$  direction, and  $yp$  is positive  $y$  direction.

Once the maximum correlation and the lag time for each annual inflow data series are obtained,

the monsoon shift pattern can then be calculated based on the consecutive occurrence probability with a lag time of zero. Also, the period of monsoon shift from the initial condition can be determined based on the lag time average over the analyzed periods.

The identification of the monsoon pattern is then used as input for estimating the realization of the planting area expressed as a cropping intensity and used for updating the crop water demand. The relationship of the monsoon pattern on the irrigation water balance can be described through the following scheme.



**Figure 1.** Relation scheme of the predicted monsoon on the irrigation water balance.

The analysis of irrigation water balance includes components of water availability expressed as inflow, which is calculated based on the Mock model [10-11] and water demand expressed as outflow. The outflow refers to the crop water demands as well as the water loss due to actual evaporation in the reservoir [12-13]. Calculation of the dependent inflow model using the F. J. Mock method requires data including average area rainfall, potential evapotranspiration, total rainy days, groundwater flow recession, and infiltration rate. The calibration of the generated inflow model is conducted by comparing it with the observed discharge.

For outflow components, the crop water demand is defined as the volume of water needed to compensate for the deficit between potential evapotranspiration and effective precipitation over the crop-growing period and change in soil moisture content. This circumstance varies considerably with climatic conditions, seasons, crops, and soil types.

Furthermore, the standard operating rule of irrigation intake is determined based on the inflow and outflow components, which are expressed as the reliability index. The iteration process is carried out to determine the optimum value of the reliability index and crop intensity [14]. In this case, the standard operating rule of irrigation intake can be determined under circumstances of dry, normal, and wet periods. The actual crop intensity and the standard operating rule of irrigation intake are then updated based on the predicted monsoon pattern.

### 3. Results and Discussion

#### 3.1. The spatial-temporal variance of seasonal precipitation and evapotranspiration.

The condition of the local monsoon pattern cannot be separated from the influence of the surrounding climatic conditions. In this case, the spatial and temporal patterns of rainfall and the evapotranspiration rates were studied throughout Lombok Island. The seasonal and temporal changes were analyzed based on the satellite data using TRMM 3B42RT Daily v7 for spatial rainfall information and GLDAS CLSM025 DA1 D v2.2 for spatial evapotranspiration rates. Based

on the results for over ten years, the rainfall conditions in the Tibu Kuning irrigation service area tend to be low to moderate with an average annual rainfall of  $7.5 \times 10^3$  mm (see Figure 2). On the other hand, the evapotranspiration rate can be estimated at  $4.0 \times 10^{-5}$   $\text{kgm}^{-2}\text{s}^{-1}$ , which is higher than in other regions. It should be noted that the availability of evapotranspiration data using satellite is limited in areas close to the sea. In general, the potential water availability on the west side of Lombok Island, including the Tibu Kuning irrigation service area, is relatively lower than the north side region.

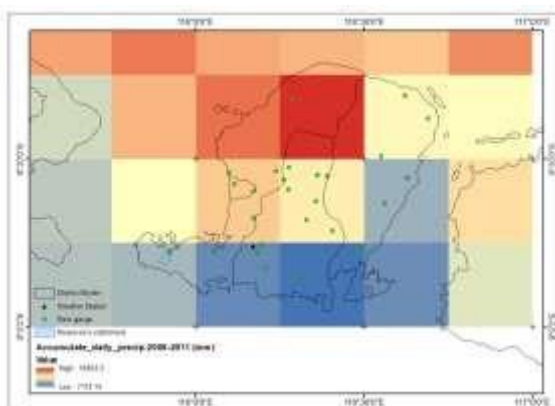
Even though the potential water availability in the study area is relatively low, but by considering the spatial scale throughout Lombok Island, the rainfall amount has increased by 18% per year, where the largest increase was obtained in 2006-2011 (see Figure 3). The spatial variation of rainfall amount increased by 2.90% in 2006-2011 but decreased by 0.53% in 2012-2017. It indicates that the level of anisotropic rainfall has decreased in 2012-2017, which means the spatial rainfall distribution throughout Lombok Island is relatively uniform.

In general, the spatial feature of the evapotranspiration rate is similar to the spatial rainfall conditions, in which the higher evapotranspiration rates distribute over the south and west sides of Lombok Island. From 2000 to 2017, there was a decrease in the average evapotranspiration rate by 3.5% per year. The spatial variation of the evapotranspiration rate decreased by 9.94% in 2006-2011 and significantly decreased by 19.98% in 2012-2017. It was found that the evapotranspiration rate distribution is also relatively uniform throughout Lombok Island.

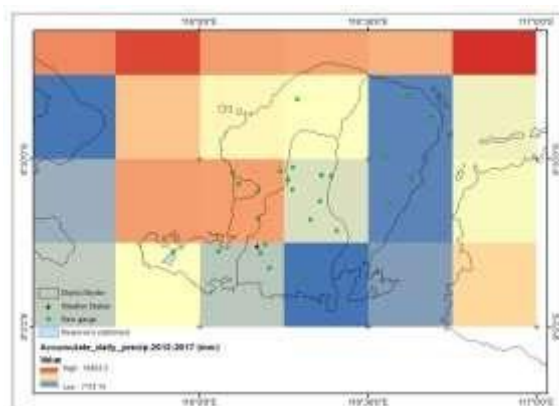
### 3.2. The seasonal monsoon patterns

The seasonal inflow in the study area was calculated for 25-year. The inflows generated for these periods are summarized in Figure 4. The average seasonal inflow shown by the bold line indicates that the rain season starts in October. The peak condition of the rain season mainly occurs in January-February and gradually decreases up to July-August for the peak condition of the dry season. The average peak inflow was estimated at  $860 \times 10^3$  cubic meters.

The phase correlation analysis was conducted for 20-year performing the response of lag time distribution of yearly seasonal inflow. Figure 5 shows that the median distribution of the lag time mainly occurs at (+) 1-2 or (-) 1-2. It should be noted that the lag of 1 is equivalent to a 15-day shifted from the initial condition with an earlier (-) or a later (+) shifts. It indicates that the monsoon pattern shifted periodically with the maximum shifting period is about one month.



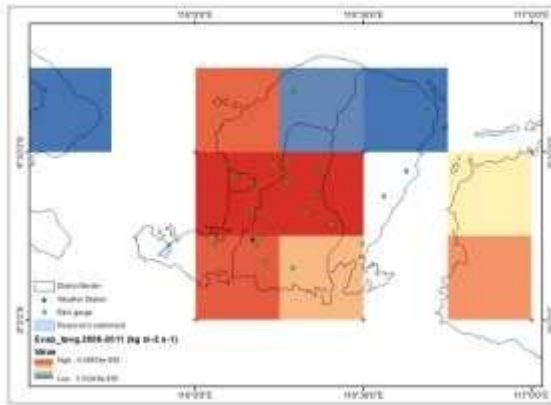
**Figure 2.** Spatial distribution map of rainfall amount (2006-2011)



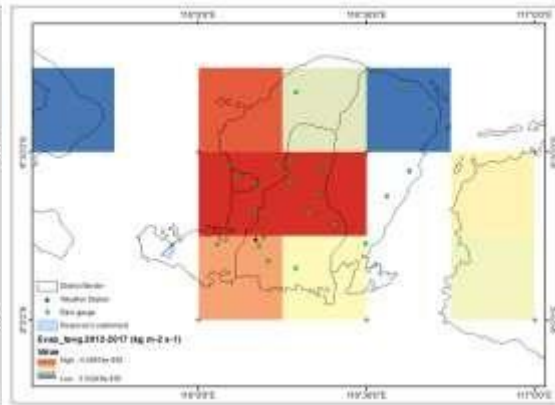
**Figure 3.** Spatial distribution map of rainfall amount (2012-2017)

The interval of shift pattern is then calculated based on the consecutive occurrence probability with a lag time of zero. This condition indicates that the periods of the seasonal inflow remain constant. The results show that the alteration of seasonal inflow has an interval of 3-year. Figure 6

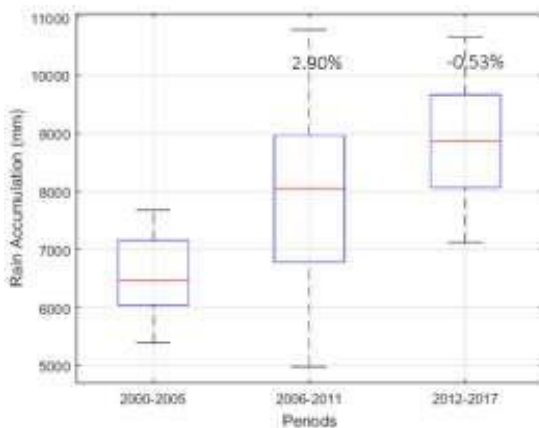
shows that phase correlation of seasonal inflow for less than 3-year consecutive periods obtain the maximum correlation (0.88) at a lag time of 0, while for more than 3-year, the maximum correlation drops significantly (0.62) and obtains a lag time larger than 0.



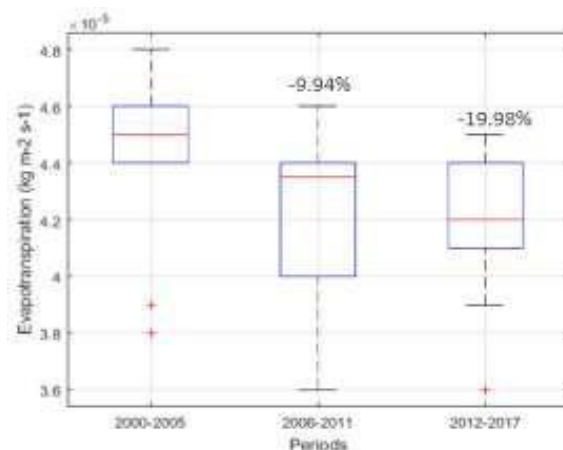
**Figure 4.** Evapotranspiration rates throughout Lombok island (2006-2011)



**Figure 5.** Evapotranspiration rates throughout Lombok island (2012-2017)



**Figure 6.** Spatial-temporal variance of rainfall amount.



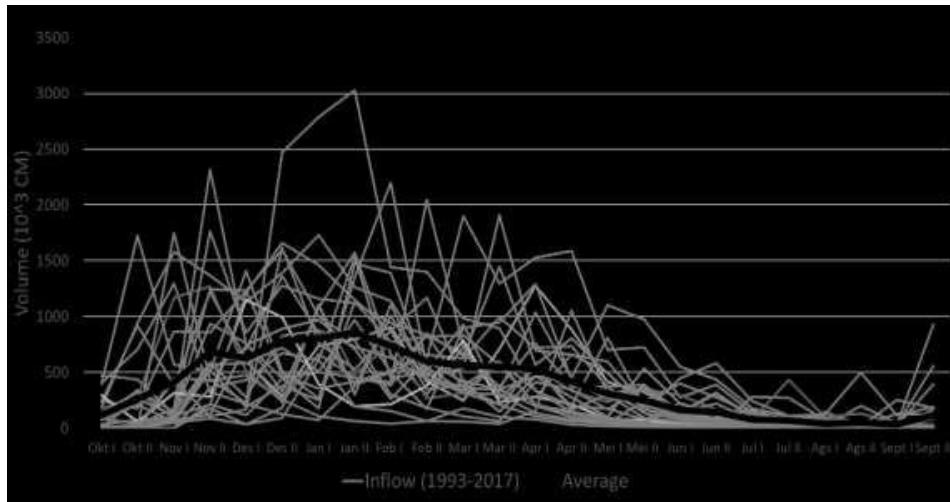
**Figure 7.** Evapotranspiration rates (right) throughout Lombok island

### 3.3. Reliability index of irrigation water balance

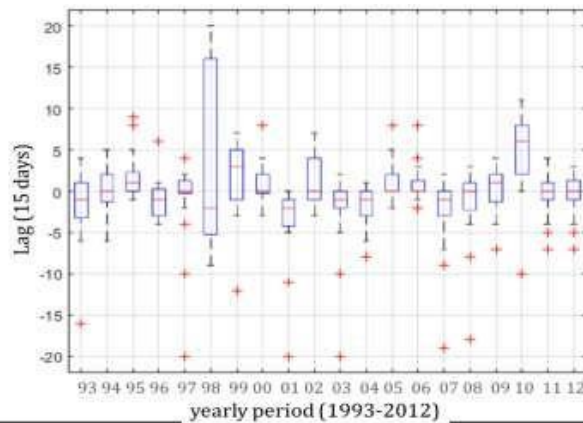
The reliability index was determined based on the optimization of the standard operating rule of irrigation intake under dry, normal, and wet periods with the crop intensity performances. By considering the actual cropping calendar information, the reliability index and crop intensity relation in the study area can be analyzed (see Figure 7). The monsoon pattern predicted from seasonal inflow is used to determine the cropping schedule for the upcoming periods. Furthermore, the validation process is carried out to ensure the relationship between monsoon shift pattern and irrigation water balance under dry, normal, or wet periods through the calculation of the standard operating rule of irrigation intake.

Based on the bar chart graph shown in Figure 8 it shows the alteration of reliability index and crop intensity following the monsoon shift pattern. It was found three years consecutive dry period from 2014-2016. This result corresponds to the seasonal inflow pattern, which has shift periods of 3-year. By the end of 2016, there is an increase in reliability index, and crop intensity correspond to the alteration of the seasonal monsoon pattern. In this case, adjustments of the

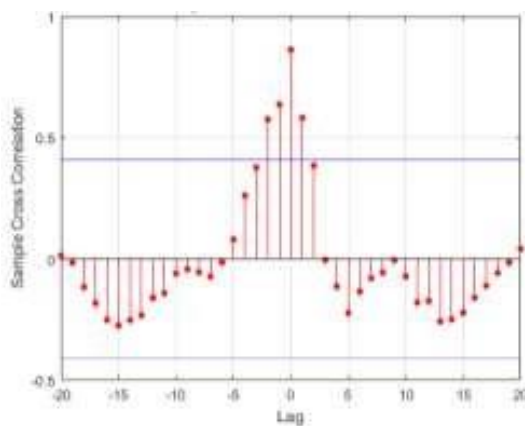
standard operating rule of irrigation intake are required.



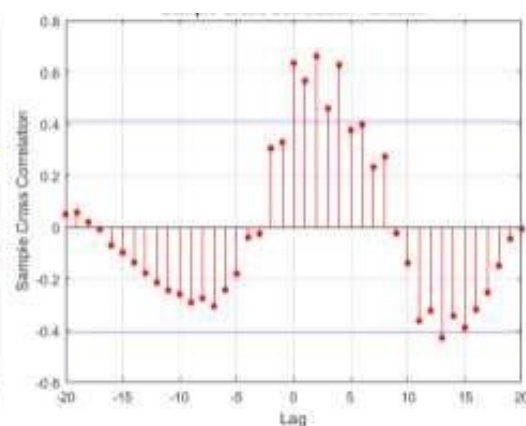
**Figure 8.** The seasonal inflow condition for 25-year (1993-2017).



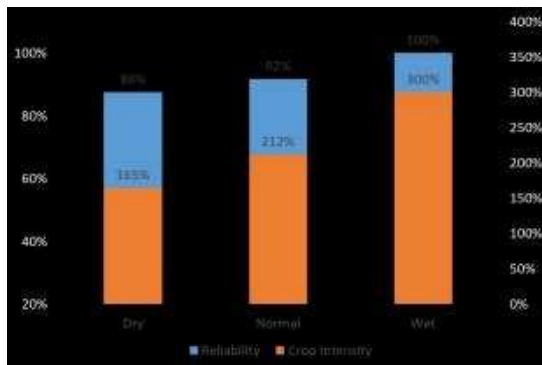
**Figure 9.** The lag time distribution of yearly seasonal inflow.



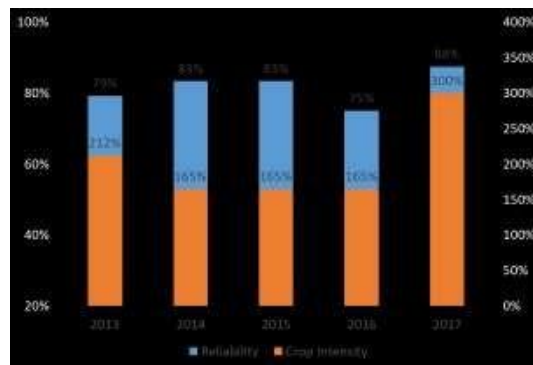
**Figure 10.** Phase correlation analysis of seasonal inflow for less than 3-year



**Figure 11.** Phase correlation analysis of seasonal inflow for more than 3-year



**Figure 12.** Reliability index and crop intensity relation under dry, normal, and wet conditions



**Figure 13.** Validation of reliability index and crop intensity performance based on seasonal monsoon pattern information.

#### 4. Conclusions

The influence of monsoon shift pattern on the technical irrigation service has been proven through the reliability of standard operating rule of irrigation intake and crop intensity performances. It was found that the monsoon shift pattern in the study area has an interval of 3-year with the maximum shifting period is about one month. This result corresponds to actual field conditions found that the beginning of monsoon season periodically shifted within one month. The benefit obtained from this study is the possibility to improve the efficiency of seasonal irrigation water services. Besides, the appropriate information to farmers for preparing the cropping activities could be provided. Hence, the risk of losses borne by farmers could be diminished.

#### Acknowledgement

We sincerely appreciate the River Basin Office of Nusa Tenggara 1 for providing the rainfall and climatological data.

#### References

- [1] Gadgil S, Francis P A 2012 *Oceans and the Indian Monsoon* 1–58.
- [2] Tjasyono H K, Bayong B 2008 *International Symposium on Equatorial Monsoon System* 1–11.
- [3] Safdar F, Khokhar M F, Arshad M, Adil I H 2019 *Advances in Meteorology* **1–14**.
- [4] Hidayat T 2011 *Jurnal Agrista Unsyiah*.
- [5] Sulaksana N, Sukiyah E, Sjafrudin A, Haryanto E T 2014 *Jurnal Ilmu-Ilmu Hayati Dan Fisik* **16** 29–34.
- [6] Koei N 2017 *The Study on Capacity Development for Jeneberang River Basin Management II* 1–16.
- [7] Departemen PU 2019 *Penyusunan Manual OP Bendungan Dan Pola Operasi Waduk TibuKuning Dan Waduk Telaga Lebur*. Lombok.
- [8] Mohamed M, Helmi S A A K, Fkirin M, Badwai S M 2013 *National Radio Science Conference Proceedings* **1** 347–58.
- [9] Peeters M H G 2003 *Implementation of the Phase Correlation Algorithm - Motion Estimation in the Frequency Domain* 7839.
- [10] Chandrasasi D, Limantara L M, Juni R W 2020 *Earth and Environmental Science* **437** 1.
- [11] Komariah K, Imas I, Matsumoto T 2019 *Journal of Water and Environment Technology* **17** 203–17.
- [12] Susilo S, Eko G, Wahono E P 2016 *Simulasi Waduk Sukaraja III, Kecamatan Margatiga , Kabupaten Lampung Timur* **3** 381–96.
- [13] Departemen PU 2017 *Diklat Teknis Perencanaan Bendungan Urugan Tingkat Dasar* 1–9.
- [14] Sokolov A A 1974 *The Unesco Press: Paris* 1-118.