Effect of toposequence on rice (Oryza sativa L.) by intermittent irrigation in Bali

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Abstract
The research of toposequence effect on rice aims to study effect of toposequence on rice planting season by different way of irrigation in Yeh Ho watersheds Tabanan Bali. This research used some varieties of rice namely Mekongga, Inpari 1 and Inpari 10 Laeya. The result showed that toposequence had significant effect on milled dry paddy (GKG). Upstream toposequence able to produce rice about 6450 kg ha⁻¹, middle was about 6460 kg ha⁻¹ and downstream was about 7260 kg ha⁻¹ by significantly different. Irrigation interval every eight days capable to produce 7400 kg ha⁻¹ of rice which was 17.3% higher than continuously irrigation production about 6280 kg ha⁻¹. Also, irrigation interval every four days can produce 6490 kg ha⁻¹ of rice which was 12.3% higher than continuously irrigation production about 6280 kg ha⁻¹. Varieties of Mekongga produce 6800 kg ha⁻¹ of GKG which was 5% lower than Inpari 10 Laeya varieties, 4.1% lower than Inpari 1 varieties. Then, Inpari 1 produce 7080 kg ha⁻¹ of GKG which was 0.89% lower than Inpari 10 Laeya. Irrigation interval every eight days capable to produce highest of GKG compared to others irrigation interval. It can be concluded that toposequence had significant different on rice production.

Keywords: Toposequence, lowland rice, intermittent irrigation

1. Introduction
In Bali, water supply comes from 162 of rivers which 82 of them flow continuously to sea throughout every year. Those rivers comes from watersheds is about 283,2 km² [1]. Toposequence is series of land related in different altitude with one another due to topography effect. Topography is the shape of earth’s surface in the form of elevation, steepness of the slope to light and direction of the mountain range. Characteristics of water resource from each toposequence in rice plantations according to water regime [2] are (a) pluvial position, water comes from rainfall in above toposequence which had sloping to steep slope and rice field doesn’t flood (rain catchment area), (b) freatic position, water comes from rainfall, soil water, and irrigation water, (c) pluksial position, water comes from rainfall, surface flow and river. Based on that definitions, it can be said watersheds are one of ecosystem which organism, biophysics environment and chemical components interat dynamically and balance of absorption and expenditure for each materian and energy.

Increased altitude followed by decreasing in temperature, increasing rainfall and wind speed. Maximum temperature would decrease about 0.6°C for each 100 m and minimum temperature decrease about 0.5°C for every 100 m increase [3]. According to Atlas Sumberdaya Tanah Eksploasri Indonesia [4], soil kinds are spread in Yeh Ho watersheds namely Vertisol, Inceptisol, Andisol dan Entisol (Figure 1).
The water utilization area is increasingly reaching the water conservation area in the form of terraced rice fields due to the pressure of the population who need agricultural land. Lacking of attention to watershed conservation and neglecting of local wisdom in watershed management leads to degradation of forest, land and water resources [6]. Watersheds (DAS) are generally defined as a stretch of area / area which is limited by a topographic barrier (the ridge that receives, collects rainwater, sediment and nutrients and flows it through tributaries and enters the main river eventually into the sea or to the lake or reservoir. Then, all regions are divided into watershed units [7]. There are a lot of DAS units due to 45% of Indonesia’s mainland are hills and mountains [8]. The total area of hills and mountains reaches 88,171 million ha, which is divided into 3 types, namely: (1) type A, very dispersed, (2) type B, continued but separated by rather clear boundaries, and (3) type C, continued with several overlays but separated by clear boundaries. The general basic for utilization of natural resources including water resources is agroecosystem properties, namely: productivity, stability, sustainability and equitability.

1. Productivity: introduced cultivation technique capable to increase production efficiency by reducing utilization of external input.
2. Stability: introduced cultivation technique stabilize productivity in any condition including biotic and abiotic stresses.
3. Sustainability: introduced cultivation technique can support production stability sustainably.
4. Equitability: level of productivity, stability and sustainability could be enjoyed by farmers in all regions (upstream, middle, downstream). The main basic of Water Use Efficiency (WUE) or water production efficiency by using these formula:

![Figure 1. Distribution of soil types in Yeh Ho watersheds, Tabanan, Bali [4], [5].](image)
WUE = \frac{Grain yield\ (\ rice\ yield)(kg)}{(water\ consumption\ )\ (m^3)}

WUE would enhance if it can fulfill these three requirements such as: (a) WUE would enhance if rice productivity does not change in reduced water consumption, or (b) WUE would enhance if rice productivity increase in constant water consumption, or (c) WUE would enhance if rice productivity increase in reduced water consumption. Based on above requirements, third requirement is the most ideal because introduction of technology innovation able to enhance productivity and suppress amount of input.

(5) Drainage: water loss is still high and
(6) water ways and embankment is less maintained.

This study aims to study:
- toposquence effect on productivity and rice yield in different cultivation season,
- to obtain compatible intermittent irrigation method for each toposquence,
- to understand the relationship between toposquence and supporting factor of rice productivity in Yeh Ho watersheds Tabanan-Bali.

2. Materials and Methods

2.1 Materials

This research was carried out in farmer’s land at Subak regions in a series of field experiments in the subak region representing upstream toposquence, middle toposquence and downstream toposquence from Yeh Ho watershed. Experiment of upstream toposquence was carried out in Wangaya Subak (-8.342156.411.51326948), Penebel subdistrict. Altitude of this location is about ±564 meter from above sea level. Experiment of middle toposquence was conducted in Meliling Subak (-8.513658.115.081126), Kerambitan subdistrict at ±152 meter above sea level. Experiment of downstream toposquence was conducted in Tibu Biyu Subak(8.528779.115.084084), Kerambitan subdistrict at ±40 meter above sea level. Each toposquence had one experiment unit for three times of cultivation season.

2. 2 Methods

Each experiment used split plot experiment design. Then, data were analyzed by using one-way analysis variance (ANOVA) to know significance different of water and varieties treatment at significance level of 5% dan 1%. If result showed significant different, then data were analyzed by using Duncan Multiple Range Test at significant level of 5% and 1% and combined analysis variance to determine the specific differences of treatments [9].

3. Result

Soil Biophysical Characteristics and Soil Kind

According to Atlas Sumberdaya Tanah Eksplorasi Indonesia [4], soil kinds in Yeh Ho watersheds are vertisol, inceptisol, andisol, entisol. Soil kinds in upstream, middle and downstream toposquence has been recorded at land mapping unit 169 \textit{(Udirtand associated with Udorthent)}, land mapping unit 151 \textit{(Hapludand associated with Eutrudent)} and land mapping unit 134 \textit{(Hapludand associated with Endoaquept)}. Generally, soil kind in toposquence experiment are included andisol. Andisol dominate the toposquence, and two others soil kinds are entisol and inceptisol by following these characteristics such as 1 \textit{Andisol}: fertile soil (contain a lot of soil organic matter, highly phosphate resistancy). Low soil bulk density, highly water holding capacity, resistant to erosion and drought. 2 \textit{Entisol}: young soil,
it can be found in all of toposequence including hillsides and active mountains. Variance of soil fertility relies on topography and level of erosion. 3 Inceptisol: young soil by shallow cross section especially in hillsides/mountains, soil characteristics very variance relies on soil parent matter and soil texture is smoother than sand, pH of soil acidity are variance up to neutral. Andisol dominate soil kind in experiment toposequence at upstream, middle and downstream.

Climate
The main climate character used in the Atlas Sumberdaya Iklim Pertanian Indonesia by 1: 1,000,000 scale is a rainfall pattern [10]. Rainfall pattern of Yeh Ho watersheds included type III A in upstream watersheds toposequence, type III C in middle toposequence and type III A in downstream watersheds toposequence.

Dried Paddy, Result Component, Straw and Water Utilization Efficiency
Result of wet paddy after converting to dried paddy (water content 14%) showed that significant different between cultivation seasons. MT1 able to produce highest dried paddy about 7240 kg ha\(^{-1}\) and this result significantly different from MT2 (6690 kg ha\(^{-1}\)) and MT3 is about 6230 kg ha\(^{-1}\). Dried paddy of MT2 was higher than MT3 and also they were significantly different. Toposequence experiment showed significantly different result to dried paddy result. Dried paddy of upstream toposequence was about 6450 kg ha\(^{-1}\), dried paddy of middle toposequence was about 6460 kg ha\(^{-1}\). Both of them were lower than dried paddy of downstream toposequence was about 7260 kg ha\(^{-1}\) by significantly different. Interval irrigation every eight days (7400 kg ha\(^{-1}\)) increase result up to 17.3% compared to continuously irrigation (6280 kg ha\(^{-1}\)) and interval irrigation every four days by up to 12.3% (6490 kg ha\(^{-1}\)). Production of dried paddy from Mekongga varieties (6800 kg ha\(^{-1}\)) was lower up to 5% than Inpari 10 Laeya varieties and lower up to 4.1% than Inpari 1 varieties. Dried paddy of Inpari 1 was lower up to 0.89% than Inpari 10 Laeya varieties (7080 kg ha\(^{-1}\)). MT 1 capable produce highest of dried paddy result, and also treatment of interval irrigation every eight days and Inpari 10 Laeya varieties supported by their higher of result component. Result of downstream toposequence was not supported by result component due to CV was higher more than 15% for panicle, filled grain and paddy/straw ratio.

4. Discussion
Relationship between dried paddy result and result component was analyzed by stepwise regression model, showed that : (1) number of panicles when harvested was about 24.39%, (2) number of tillers when harvested was about 21.95%, (3) number of tillers at 49 days after planting was about 21.95%, (4) number of filled grain/panicles was about 17.07%, (5) number of tillers at 49 days after planting was about 7.32%, (6) number of straw was about 4.88% and (7) paddy/straw ratio was about 2.44%. Number of productive tillers when harvested showed significantly different to result components. Number of panicles was effected by number of tillers when harvested and it had same result with 49 days after planting’s result, filled grains/panicles percentage. Paddy/straw ratio affected dried paddy result. MT1 water consumption about 5983 m\(^3\) ha\(^{-1}\) produce water utilization efficiency about 1.01. MT2 water consumption about 6558 m\(^3\) ha\(^{-1}\) produce water utilization efficiency about 1.02. MT3 water consumption about 6168 m\(^3\) ha\(^{-1}\) produce water utilization efficiency about 1.03. Upstream toposequence’s water consumption about 4777 m\(^3\) ha\(^{-1}\) produce water utilization efficiency about 1.35. Middle toposequence’s water consumption about 6368 m\(^3\) ha\(^{-1}\) produce water utilization efficiency about 1.14. And last, downstream toposequence’s water consumption about 6368 m\(^3\) ha\(^{-1}\) produce water utilization efficiency about 1.14.

Continuously irrigation’s water consumption about 5508 m\(^3\) ha\(^{-1}\) produce produce water utilization efficiency about 1.14. Four days interval irrigation’s water consumption about 5547 m\(^3\) ha\(^{-1}\) able to produce water utilization efficiency about 1.17. Eight days interval irrigation’s
water consumption about 5967 m$^3$ ha$^{-1}$ able to produce water utilization efficiency about 1.24. Mekongga varieties was used in this study. Mekongga varieties’s water consumption about 6538 m$^3$ ha$^{-1}$ able to produce water utilization efficiency about 1.04. Then, Inpari 1’s water consumption about 5912 m$^3$ ha$^{-1}$ capable produce water utilization efficiency about 1.14. Then, water utilization efficiency of Inpari 10 Laeya’s water consumption about 6436 m$^3$/ha was 1.10. Combined analysis variance result showed that water utilization efficiency result was not significantly different, it mean that eventhough paddy had harvesting result signicantly different, water utilization efficiency was not different. It may caused by plant’s water consumption capability for growing. MT1’s water consumption was low and downstream toposequence’s water consumption was lowest. Interval irrigation every eight days can be highest water utilization efficiency.

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Conclusion
The results of the study showed that toposequens affected rice production. significant effect on the results of milled dry grain (MPD). In the upstream toposequens: 6,450 kg ha$^{-1}$, middle 6,460 kg ha$^{-1}$, downstream 7,260 kg ha$^{-1}$ with significant differences. Irrigation 8 days once 7,400 kg ha$^{-1}$ increases yields by 17.3% from continuous irrigation 6,280 kg ha$^{-1}$ and irrigation 4 days once 6,490 kg ha$^{-1}$ 12.3%. The Mekongga variety produces 6,800 kg ha$^{-1}$ of MPD 5.0% lower than the Inpari 10Laeya variety, 4.1% lower than the Inpari1 variety. Inpari1 is lower by 0.89% than Inpari 10Laeya 7,080 kg ha$^{-1}$. The highest MPD result is watering once every 8 days.

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