Assessing the combined impacts of dams upstream, climate change, drought, tide, and sea level rise on the temporal variation of paddy land in Tien Giang province

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Assessing the combined impacts of dams upstream, climate change, drought, tide, and sea level rise on the temporal variation of paddy land in Tien Giang province

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Abstract. Environmental changes have become a global issue of universal interest because of its influence sphere and effect level on humanity. The Mekong River Delta, in general, and Tien Giang Province, in particular, play a crucial role in providing food to Viet Nam and all over the world more broadly. However, there have been fluctuations in planted areas of rice and rice output in recent decades due to the damaging consequences of many natural and man-made agents. In this study, partial least-squares (PLS) regression was applied for quantitative analysis in the combined impact of dams upstream, climate change, drought, rising tide and sea level on change of paddy land; the geo-statistic was used for demonstrating the linear of variations among components in the mentioned nexus. Then, the impact factor, flowchart and equation were established for demonstrating their influences on the planted area of rice in the province. The results showed that the hydropower dams are the largest agent which create the variations of paddy land in the study area, by R^2 = 0.726.

1. Introduction

Tien Giang is one of thirteen provinces in Lower Mekong River Delta, which covers about 5% of the Mekong River basin, and in coastal areas of Vietnam. There will be several advantages of the geographical location such as the wealth of water resource from river upstream and the correction of river runoff by Tonlé Sap Lake (Cambodia). On the other hand, the Mekong River Delta (MRD) and particularly Tien Giang Province (TGP) play a crucial role in contributing the output of agriculture in the economic development of Vietnam and as a part of rice production over the world [1].

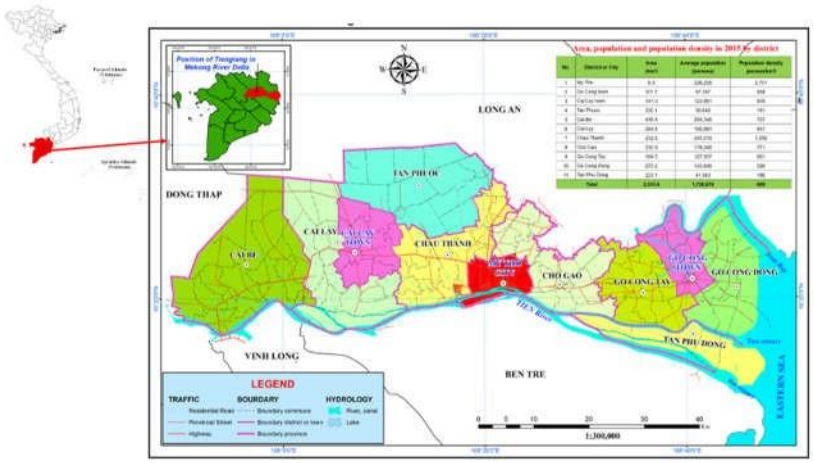
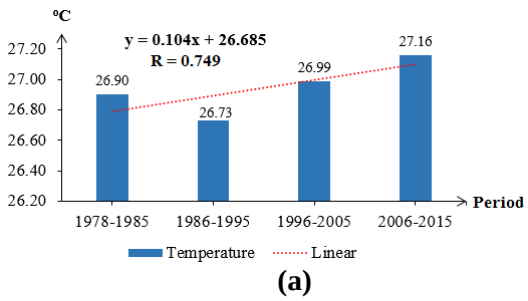


Figure 1. Position of the study area in Mekong River Delta and Vietnam more broadly

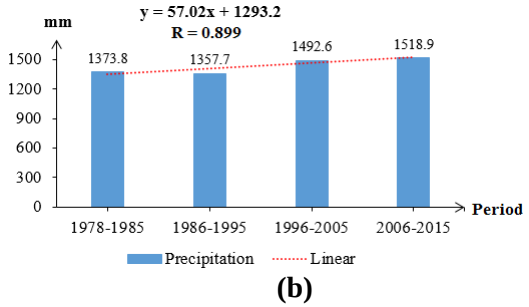
However, in recent years, climate change and sea level rise have become more noticeable and serious under the form of changing temperature, fluctuated rainfall, drought, water shortage, salt water intrusion, rising tide, sea level and so on [2] *(see Fig 2a,b,c,d,e)*

Besides, at the basin scale, one hundred and thirty – three hydropower dams have been built or planned [3], [4] with six dams operating already in China and eleven mainstream dams being planned in Thailand, Laos PRD, and Cambodia [5] (*see Fig 2f*). These hydropower dams will essentially destroy the seasonal water flow variability in the upper Mekong River and cause extreme effect on lower areas [6].

Overall, all of them have influenced on the agricultural development and particularly the paddy land in the study area [7]. Thus, it threatens the sustainable development in the MRD.



(a)



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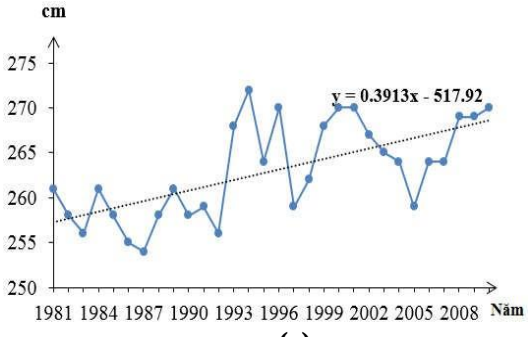

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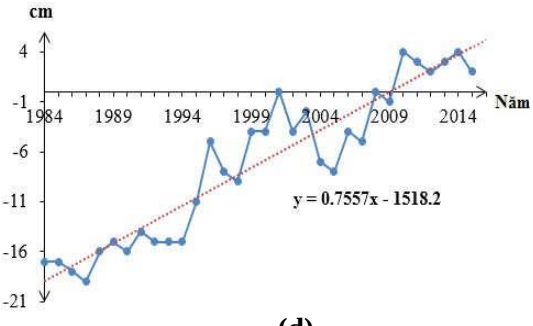

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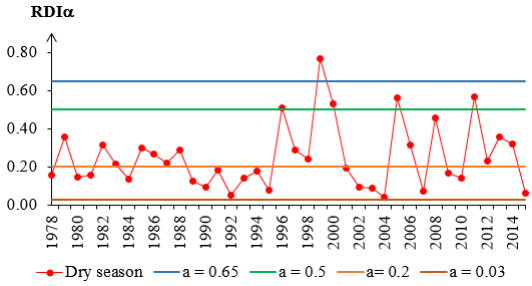
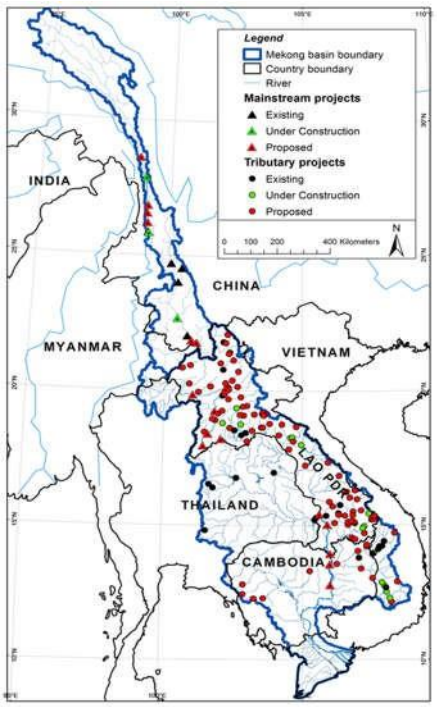


(e)

Note: *RDIα < 0.03: Hyper-arid; 0.03 < RDIα < 0.20: Arid; 0.20 < RDIα < 0.50: Semi-arid; 0.50 < RDIα < 0.65: Dry sub- humid*



(f)

Source: Mekong Flow. http://mekongriver.info/hydropower

Figure 2. The change in average temperature (a) and mean rainfall (b) decade, the probability of drought in dry season (c) in the TGP (My Tho station) during period of 1978 – 2015; the fluctuation of sea level (Vung Tau gauging station – d) and average water level (Vam Kenh hydrological station – e); Mekong mainstream Dams (f)

Describing paddy land in quantitative terms and testing the importance of its impact factors have been proposed by empirical statistical analysis. A variety of statistical methods, such as multiple linear regression, canonical correlation analysis and principal component analysis have been used in these studies [8]. Partial least squares (PLS) regression is a forceful multivariate statistical method that permits users to implement an extensive series of analyses [9].

The major damaging agents of change and mistakes in the input data from complex systems can be provided as a quick overview and help to identify in this complex system. It overcomes the problems of over-fitting, multicollinearity and outlines [9], [10] while it finds factors that explain a significant proportion of the information content between one dependent variable versus many independent variables[11]. Hence, it is the perfect tool to research the impact of components in the nexus of dams upstream, climate change, drought, tide, and sea level rise on planted areas of paddy in TGP using the PLS regression.

2. Materials and methods

2.1. Data

In this study, the meteo-hydrological statistics for doing research includes average monthly temperature, monthly precipitation at My Tho meteorological stations, tide at Vam Kenh hydrological station, and sea level at Vung Tau gauging station during the period of 1995 – 2015. The data were provided by National Centre of Meteorology and Hydrology in Vietnam.

Table 1. List of stations

Name	**Location**	**Longitude**	**Latitude**	**Type**
My Tho	Tien Giang	106.39E	10.35N	Meteorology
Vam Kenh	Tien Giang	106.73E	10.27N	Hydrology
Vung Tau	Ba Ria – Vung Tau	107.05E	10.22N	Gauging

In addition, the data for the fluctuation of paddy land in the study area was collected from Tien Giang Statistical Yearbook while the number of dams was compiled by the Mekong River Committee reports from 1995 – 2015.

2.2. Methods

2.2.1. Testing hypotheses. The confidence level of correlation coefficient and linear equation was tested by H_o hypotheses. By the mentioned method, the correlation coefficients with survey sampling will be good enough, if they are available by standard of $\alpha = 0.05$ (*see Table 2*).

Table 2. Confidential standards of correlation coefficient

n-2	10	20	30	40	50	60	70	80	90	100
α = 0.05	0.567	0.423	0.349	0.304	0.273	0.250	0.232	0.217	0.205	0.195

2.2.2. Partial least-squares (PLS) regression method. The development of PLS regression began in the 1970s by Herman O.A. [12]–[14]. It is a statistical model that is used to assess correlation among orthogonal latent variables across the input variables and relates them to the target variables [15]. PLS has applied and achieved great success in scientific fields, such as chemo-metrics, geographical science [8], monsoon [16], and predicting yield [10], [11], [15]. In this study, PLS regression was applied for creating impact factor and assessing the consequences among components into the nexus on the temporal change of paddy land in the province that may be correlated via the Minitab 16 Statistical software.

3. Results

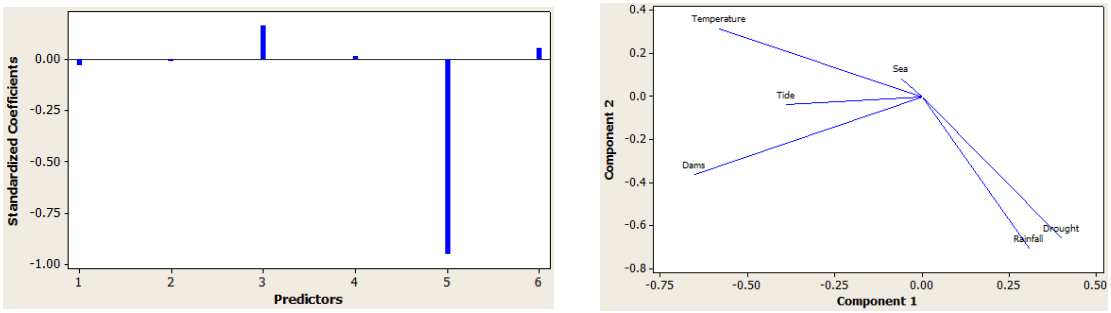
3.1. The combined impact among climate change, drought, tide level, sea level, and hydropower dam development on paddy land

The co-authors used the partial least square regression for assessing the combined influence of components into the nexus in the study area.

Source	DF	SS	MS	F	P
Regression	5	6345.71	1269.14	15.62	0.000
Residual Error	15	1218.95	81.26		
Total	20	7564.67			

Model Selection and Validation for Paddy land

Components	X Variance	Error	R-Sq	PRESS	R-Sq (pred)
Sea level		1142.14	0.849017	3671.30	0.514677
Tide level	0.355900	2688.15	0.644643	4865.21	0.356850
Rainfall	0.648303	1667.33	0.779589	3155.42	0.582873
Drought	0.789535	1324.89	0.824858	2387.79	0.684350
Temperature	0.839392	1221.92	0.838470	2153.08	0.715376
Dams upstream	0.999833	1218.95	0.838863	2065.92	0.726898



(a) (b)

Figure 3. Partial least square Standard Coefficient Plot (a) and Loading Load (b)

The model selection plot identifies the model with 5 components as the optimal model because the 5-component model has the highest predicted R^2 value. The predicted R^2 values on the plot are calculated with cross-validation. The model selection and validation table shows that the predicted R^2 value for the optimal model is approximately 0.73. The P - value in the variance analysis table (0.000) show that the regression model is statistically significant at the 0.05 level of significance. We can see that the changes of planted of rice in the province depends considerably on the fluctuations of dams upstream, temperature, drought, and precipitation. Of which, the development of dams in upper Mekong River Basin has the most damaged consequence on the variation of paddy land in the TGP. Between 2015 and 2016, the TGP and the MRD more broadly have undergone the most severe drought events over the last 90 years, causing damages to agriculture, aquaculture, and fresh water supply, especially in rice production.

3.2. Manifestations for the change of the planted area of rice in the study area under the combined effect of components into nexus

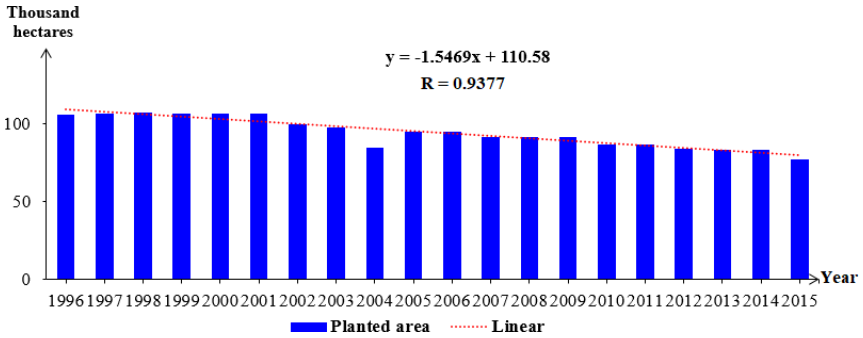


Figure 4. The temporal variation of paddy land area in TGP from 1996 to 2015 [complied from

[17] It is clear that the planted area of rice gradually went down during the 1996-2015 period

(Figure 4).

Moreover, there was a conversion in the proportion of agricultural production land. To be specific, there was an increase in the percentage of fruits land and in the meanwhile, a decrease in the proportion of planted area of rice (see Figure 5).

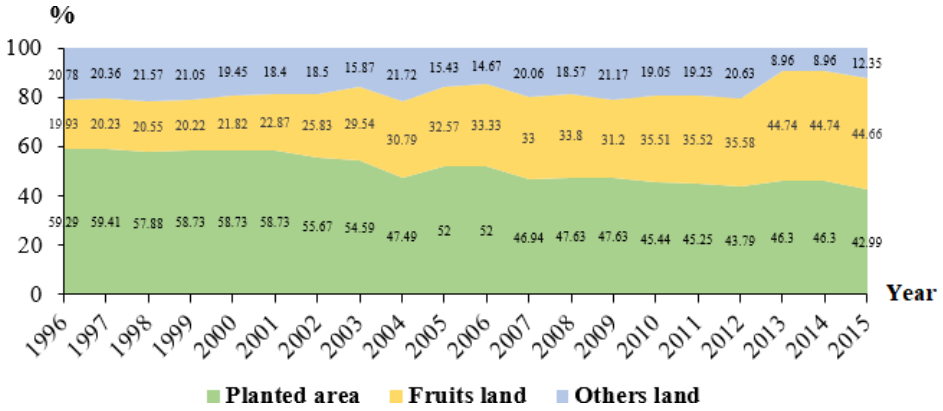


Figure 5. The temporal change in components of agricultural land in the province from 1996 to 2015 [calculated from [17]

It is simply because most fruit types adapt well with fluctuation of natural environment. It is true that the residents in the study area nowadays are planting dragon fruits to replace paddy.

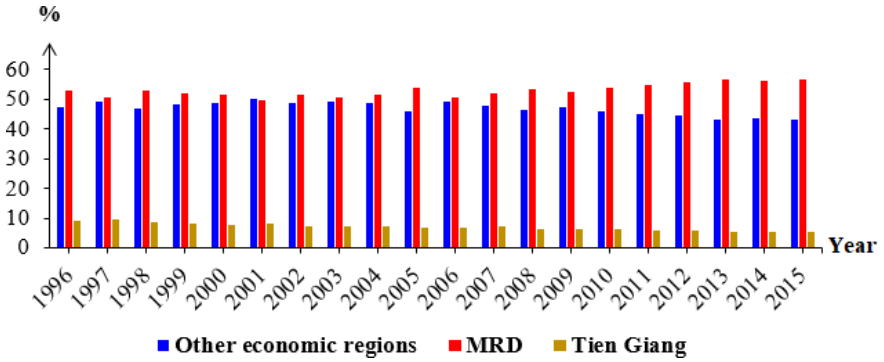


Figure 6. The percentage of paddy production in the TGP and the MRD from 1995 to 2015 in comparison with other provinces of the MRD and other regions of Vietnam respectively [calculated from [17]

Looking at the proportion of rice manufacturing in the MRD (Figure 6) was consistently over 50% during the 1995 – 2005 period in comparison with other economic regions of Vietnam (there are seven economic zones in Vietnam). However, this figure significantly decreased each year and particularly in 2016, it was the fifth largest rice producing country in the world.

4. Conclusions and discussions

The variation of paddy land and agricultural production in general in TGP and MRD are damaged by the combined consequences of dams upstream, climate change, drought, tide, and sea level rise. In addition, there are also implications in another one of the nexus.

The construction of hydropower dams in upstream Mekong River will magnify the severity to the region, even will create challenges for state and regional policymakers. The situation of drought will become more serious if eleven proposed mainstream dams in Thailand, Lao PDR, and Cambodia are constructed [3]. The rice crops are expected to lack fine sediment carrying abundant natural nutrients because of reduced exchange between rivers and floodplains. In addition, rising sea level will cause the increasing salt intrusion in dry season and inundation in rainy season. Then, those combined influences will threaten the sustainable development of rice manufacturing in the study area.

It therefore is necessary to change the forms of crops and livestock with an alternative agricultural methods. For example, the government should encourage the dwellers to breed clams

and shrimp since

they are valuable species for the economy and well-suited to the saltwater environment. In cultivation, the residents nowadays have grown dragon fruit, a drought tolerant plant, to replace rice in coastal area. Regarding the development and agricultural sustainability, it needs an approach such as the nexus theory. Nexus approach helps us to better understand the complex and dynamic interrelationships among climate change, water, energy, justice social, and food so that we can use and manage our limited resources sustainably. Climate change has had a certain effect on the water resources and especially caused water shortage in the MRD during the dry season. It is projected that the drought and saltwater intrusion will seriously impact the paddy land in the lower delta by the fluctuation of rainfall in the dry season. Therefore, the government can propose seasonal planning, using agricultural land, maintaining a reasonable and sustainable land area, and facilitating and ensuring the development of rural livelihoods. Moreover, they can also promote research on resistant, saline, and flood tolerant varieties in preparation for adaptation to future changes.

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