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Ecospatial Study and Validation of Primary Productivity in Delta Mahakam Using Remotely Sensed Data

Zakiyah, U[1]., Hartono[2], tandjung S.D[3], Gunawan, T[4]

Abstract— Observation on primary produvctivity and its validation using remotely sensed data has been conducted in Delta Mahakam ecosystem in April 2008.The aims were to observe, analyze and evaluate teh environmental variables seuch as, a-biotics, biotic and socio-cultural variables and their relation to the primary productivity of this area. Primary productivity were measured in situ as well as derived from TERRA and AQUA remotely sensed data. All data were processed using ENVI adn ER MAPPER software and analyzed using SeaDAS adn IDL. The correlation between variales from both the in situ data and the derived satellites data with in situ primary productivity and with model based primary productivity were analyzed using Multiple Regression Analysis using SPSS 16.0. The results showed that water quality parameters are within optimal range for the main variables such as, TSM, temperature, and chlorophyll *a* as well as, nitrate phosphates, conductivity, dissolved oxygen except TSM as it tends to increase. Meanwhile, the socio-cultural showed an increase of conflicts in the society and those mostly closely related to the increase of interest in the natural resources utilizations. All observed environment components, the abiotic, biotic as well as the cultural factors has affected the condition of primary productivity in this area of interest. The correlation of both satellites and *in situ* data measurements based on statistical analysis showed relatively high correlation while the correlation between the *in situ* primary productivity and remotely sensed primary productivity showed coefficient correlation 70 percents. As conclusions, the *in situ* primary productivity and from MODIS data showed relatively high suitability with value more than 70 percents. The condition of Delta Mahakam ecosystem eco spatially that was relatively degraded in terms of its environmental quality. Thus, it is suggested that the Government still need to slower the environmental degradation processes for longer sustainability of the natural resouces.

Index Terms— Ecospatial, Modeling, Chlorophyll a, Primary Productivity, Delta Mahakam, Validation, Remote Sensing.

1 INTRODUCTION

THE Oceans and its coastal areas play a key role in carbon cycle that closely related to the biogeochemistry process in it environments (Brown *et al*., 1989; Dahuri *et al*, 2004; Fasham, 2003; Kennish, 1989; Ross, 1988). To the year of 1993, almost 50 to 70 persen of the world population which approximately 5.3 billion people live in the world of its coastal areas (Kay and Elder, 1998). The complexity of the coastal areas made them difficult to manage, however the continues information with relatively good quality will be a good help in the decision making of its management (Dartoyo, 2004; Soegiarto, 1975 in Bird dan Ongkosongo,1980; Dahuri *et al*., 2004; Sidik, 2007; Prihartini, 2003).

Ecologically, the basic productivity of the earth system is primary productivity, as the key role to the higher level of productivity and higher throphic level (Bagenal, 1978; Carignan *et al*., 1998; Feldman, 1986; Harris, 1979). Primary productivity originally comes from the basic process called photosynthesis which play the basic role in acquiring the global carbon cycles (Acker, 1994; Hooker *et al,* 1992; Sathyendranath, 2000; Platt dan Sathyendranath, 1988). In this process phytoplankton as the main agent instead of bacteria (Harris, 1979 ; Parsons *et al*, 1984). Phytoplankton organism utilize chlorophyll pigments in performing this process (Berger et al, 1987; Cullen *et al,* 1992; De Vooys, 1979; Platt dan Subha Rao, 1975; Valiela, 1984).

Remote sensing technology can be used to obtained a geographical information from a wide areas (pixels) in relatively short times (Barale dan Schlittenhardt, 1993; Falkowski *et al*, 1998; Hooker *et al,* 1992; Robinson, 1985; Sutanto, 1992). This technology also one of the kind that can be used to assest the primary productivity of the ocean (Bahrenfeld dan Falkowsi, 1997a; Bahrenfeld dan Falkowski, 1997b). As well as the ocean, the coastal areas that posses a more complex problems usually showed relatively different ways compare to the ocean primary productivity (Bahrenfeld dan Falkowski, 1997b; Sathyendranath, 2000; Asanuma *et al*, 2002).

The coastal area of Kutai Kartanegara regency where the Delta Mahakam is located is in the latitude of 117o 00' 00" W to 1170 30' 00" W and longitude of 0o 00' 00" to 1o 00' 00" S East of Kalimantan, and admintratively under the local government of Kutai Kartanegara regency, East Kalimantan Province (KKP, 2007). This location was chosen as the area of interest due to its ecospatially dynamics conditions and as the passage of Indonesian Throughflow, an international currents which flow from Pacific Ocean to Indian Ocean (Anonim, 2006; Fieux, *et al*.,1996a; Fieux, et al., 1996b; Molcard *et al.*, 1996; Prihatini, 2003; Abu Daya, 2004; Sidik, 2007). Its effect to the upwelling process (Wyrtki, 1961) and seasonal variability of the phytoplankton biomas assumed will be also affected the variability in term of the primary productivity in this area (Setiapermana dan Nontji, 1980; Tomascik *et al*,. 1997a ; Tomascik *et al.*, 1997b). The area of Delta Mahakam recently under several problems that arise such as, environmental pollution that cause the degradation of its environmental quality. This condition basically due to the anthropogenic

1 Lecturer of Faculty of Fisheries and Marine Sciences, Brawijaya University Malang, Researcher
2 Director of Post Graduate Studies, Gadjah Mada University, Yogjakarta, Promotor
3 Lecturer of Faculty of Biology, Gadjah Mada University, Yogjakarta, Co Promotor I
4 Lecturer of Faculty of Geography, Gadjah Mada University, Yogjakarta, Co Promotor II

activities such industrializations which in the end causing the social conflict in the coastal areas. Thus the problems occurred has lead to the questions : how would these Abiotics, Biotics, as well as the Social environmental factors will affect the condition of the primary productivity of this area. The second is, how would the primary productivity fluctuate with those environmental condition and how would be the model of the primary productivity of this area with these ecospatial condition as well as how this model would suit to the real condition of this area.

The aims to this research are firstly to study and analyze the abiotics, biotics and Socio-cultural environmental factors to its primary productivity. Second is to synthesized and evaluate ecospatially the environmental variables which obtained in situ as well as derived from satellites and predict them as ecopatially based information, spatially and temporally as the input of primary productivity for the area of interest. Presumably this specific conditions will show relatively different model of primary productivity compare to other areas, thus this will be an interesting information to study further.

2 Research Methods

2.1 Research Area

The area of interest is Delta Mahakam coastal areas which located in the coastal areas of East Kalimantan Province (Figure 1). Sampling were done in two ways, in situ and deriving the satellites data. The in situ sampling were conducted in 30 sampling points which were divided into two days sampling activities. The satellites data used were from MODIS Terra as well as Aqua that passed in the same day and date with the in situ sampling activities.

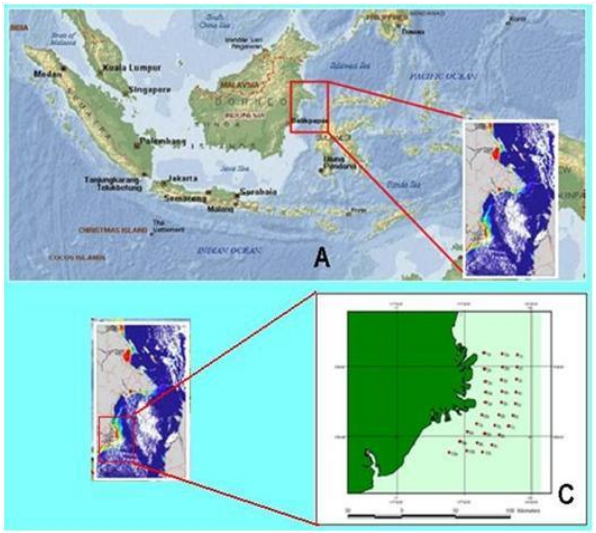


Figure 1. Location of The Research in Delta Mahakam

The in situ data includes, chlorophyll a concentration, as well as water quality parameter such as, TSM (*Total Suspended Matter*), IPAR (*Instantaneous Photosynthetic Active Radiation*) also SST (*Sea Surface Temperature*) were taken using HORIBA water checker. This research used images data from MODIS TERRA /AQUA level 2 with 1 km resolution, data of sea surface temperature, that processed by ENVI 4.5 and mapped with ER MAPPER. This research following several steps of procedures such as: (1) observation and analysis of environmental data dan preparations of the secondary data, (2) evaluation and synthesis of the predicted environmental and satellites data using SeaDAS, ENVI and ER MAPPER software, (3) Validation of the derived data using *in situ* measurements, (4) Data Analysis using Multiple Regression Analysis.

3 Result and Discussions

The area of interest is located in the coastal areas of East Kalimantan Province along 700 km at latitude of 117o 00' 00" W to 1170 30' 00" W and longitude of 0o 00' 00" to 1o 00' 00" S covers approximately 1500 km2 and within 25 km distance from Samarinda city (Abu Daya, 2004). Delta Mahakam is a modern delta and developed in the end of Halocene transgression around 5000 to 7000 year periode. The time periode of the delta formation that cover areas approximately 1300 km2 subarea of delta plain , 1000 km2 of deltan front and around 2700 km2 of pro delta area (Allen *et al.*, 1976). Mahakam river with length of around 920 km end at Delta Mahakam coastal area and its catchments area cover around 98.194 km2 made it the longest and the widest river in Indonesia (Abu Daya, 2004; Sidik, 2007).

Geologically East Kalimantan consist of rocky sediments from the tertiary and one emong the highest potensial oil and gas sources in Indonesia which has high economic values for the country. The coastal areas of delta Mahakam is located in Makassar Strait. This condition made the delta Mahakam also affected vy the Indonesian Throughflow, the famous current which flow from the Pacific Ocean to the Indian ocean through the Makassar Strait (wyrtki, 1961).

Vegetation of this areas, is dominated by natural plants from Kalimantan and tropical forest with natural resources in the coastal areas that has very high biodiversity. The coastal waters temperature average on the surface area is range between 28 till 30 degrees Celsius which found from the 1st and the 2nd in situ sampling activities. The highest temperature among those values found nearby the coastal line of delta Mahakam. The values of temperature shown to decrease toward the open ocean. Meanwhile, the values obtained from the derivation of the satellites data shown different range even has relatively similar pattern with the in situ temperature. This differences presumably comes from the time different of the sampling activities and the satellites pass over the Earth. Furthermore, this differences also found between the derived data from MODIS Terra and Aqua. The time different among those values even just shown to less than an hour will gave different result of the data. This conditions can be concluded that the area of interest has relatively high dynamic spatially and temporally.

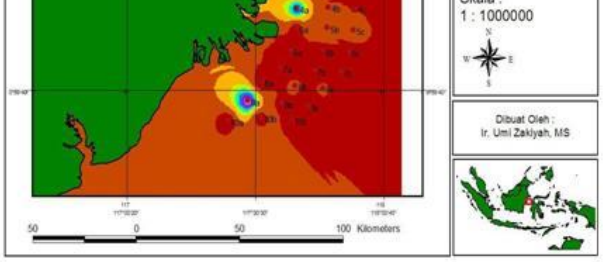


Figure 2. Pattern Distribution of Sea Surface Temperature (in ^{o}C) in Delta Mahakam Ecosystem based on in situ Measurements within 30 days Sampling Station on April 2008.

The Total suspended Solid distribution from both *in situ* and derived MODIS Terra and Aqua data showed different values but relatively have similar pattern. Sampling points with highest values are located in the same row that closest to the coastal areas. Conclusively, the pattern of (TSS) seems to be higher at the sampling points which located in the coastal areas and lesser at the sampling point further toward the ocean.

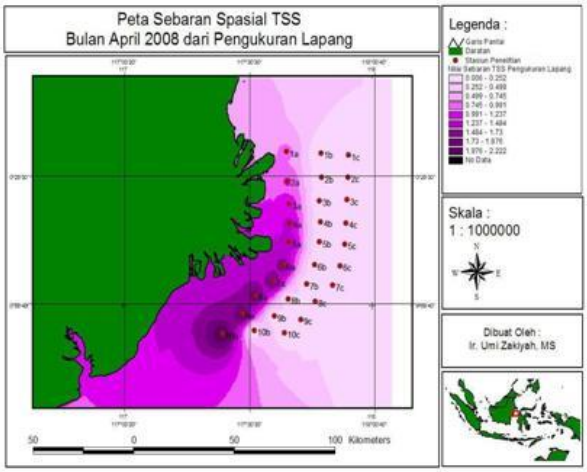


Figure 3. The Distribution Pattern of TSS (*Total Suspended Solid*) in mg/L in Delta Mahakam Ecosystem based on *In situ* measurements within 30 Sampling Station on April 2008.

The not similar values found in different sampling points from the derived data of MODIS terra and Aqua strongly presume to be due to the time differences of those two satellites passed the area of interest. The Terra satellites passes over more in the morning compare to the Aqua satellites which more in the afternoon. The differences in TSS values also due to kind of activities in the area of Mahakam watershed which affect the river flow and load to delta Mahakam. In the end, the conditions of the sampling points spatially and temporally will depend on the daily conditions of the environments.

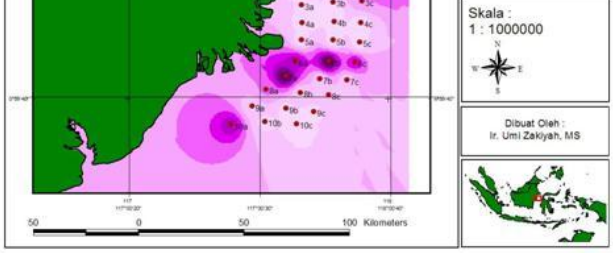


Figure 4. The Distribution Pattern of TSS (*Total Suspended Solid*) in mg/L in Delta Mahakam Ecosystem based on Derived Aqua Sattelites Image measurements within 30 Sampling Station on April 2008.

Kd 490 nm can be describe as the indicator of sediment or turbidity in the water column. The values of this variable are obtained only from satellites derived data since this parameter was not measure in situ. Based on the result, from the satellites image TERRA, the highest values still found in the stations nearest to the coastal areas and lesser and distributed evenly towards open ocean. In general it can be said that almost every variable measured, the pattern would show similarity. All the variables are presumably due to the activity in the upland that affect the flow in Mahakam river. Furthermore, when the water reach the coastal areas the currents from the river combined with the currents from the Makassar strait made the sediment flow more to the ocean in short time.

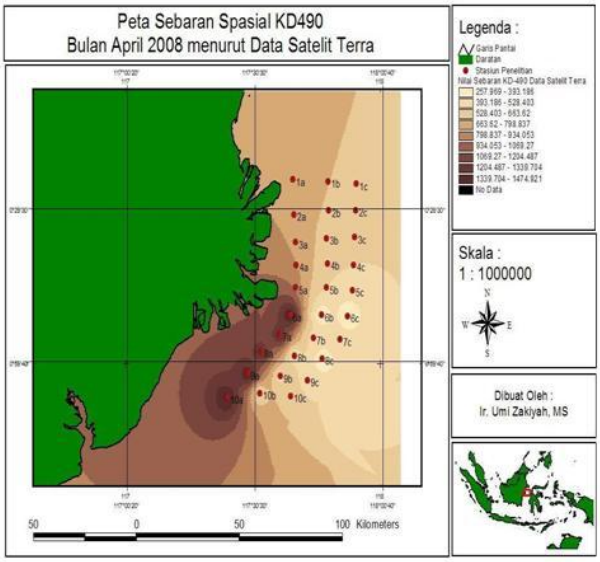


Figure 5. The Distribution Pattern of Kd 490 in mg/L in Delta Mahakam Ecosystem based on Derived Terra Sattelites Image measurements within 30 Sampling Station on April 2008

In the mean time, the IPAR variable tend not to show any distribution significantly in the area of research and this conditions that this parameter distributed in the same range of values or if there were differences in the concentrations, the values are not significantly obvious. Other variables such as pH, distributed between 6.0 and 8.5, the values of conductivity pattern in general similar other previous variables, as turbidity values are ranged between 40 to 50 mg/L and these relatively high values were due to the human activities in Mahakam river watershed, that cause high sedimentation in the river and the coastal areas.

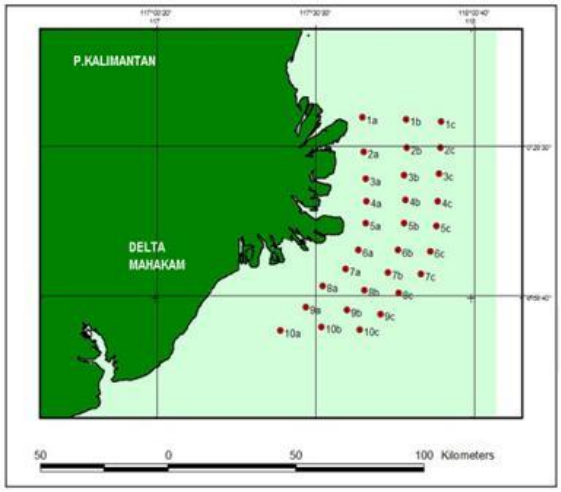
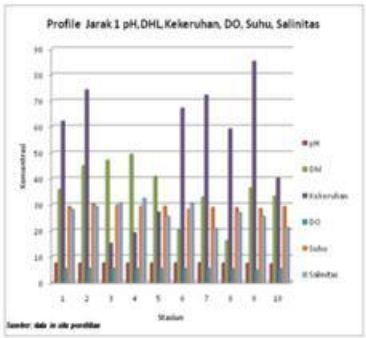


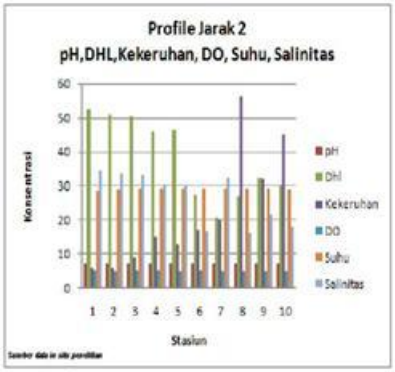
Figure 6. The Distribution Pattern of IPAR (in mg/L in Delta Mahakam Ecosystem based on Derived Terra Sattelites Image measurements within 30 Sampling Station on April 2008.

Meanwhile the dissolved oxygen were ranged between 3.04-7.5 mg/L which are relatively normal even the values were slightly under the healthy sages for the environments standard (Lee *et al*., *in* Erlina *et al.,* 2007) which is around 4 mg/L the lowest. The temperatures tends to stratified on the water column and salinity values are not fluctuated significantly, however these values are the best as well in supporting the primary productivity to be in its optimum stages.

Other variables that are important to support the life in the ocean are the nutrients such as, nitrates and phosphates. These nutrients level for sustaining the organism in the water are between 0.03 to 0.1 mg/L. The in situ analysis of these variables in the first distance stations from the coastal areas and showed different values within stations with distance II and II from the coastal areas. These nutrients tends to decrease with the increase of the water depth and distrusted more in the open ocean. The range of these nutrient are still in the level of supporting the life of organism in the water, however below this limit will come a limiting factors.

The result in chlorophyll analysis showed that within the 15 stations sampled for day 1, the values distributed between 0.2 to 2.2 mg/L. The highest values was found in one of the in situ measurements from the station closest to the coastal areas and were taken from day 1 and day 2 sampling dates. There were slightly differences between the values from the in situ measurements and the satellites derived data measurements. These due to the time differences in time when satellites passes the research locations.





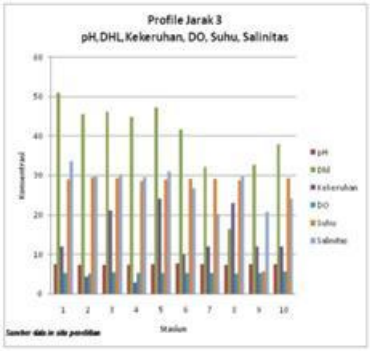


Figure 7. Histogram showed Water Quality Concentration in Delta Mahakam Ecosystem based on *In situ* measurement of the 30 Stastion for April 2008 .

The pattern of primary productivity in Mahakam delta ecosystems relatively similar to other water quality variables which higher in the coastal areas and tends to get lesser and distributed toward open oceans. The higher values are still found closest to the coastal areas and ranged between 1.2 to 1.5 gr C/m2/day. Other stations are between 0.8 to 1.19 gr C/m2/day. The Terra data showed closer values to the in situ data compare to the Aqua data.

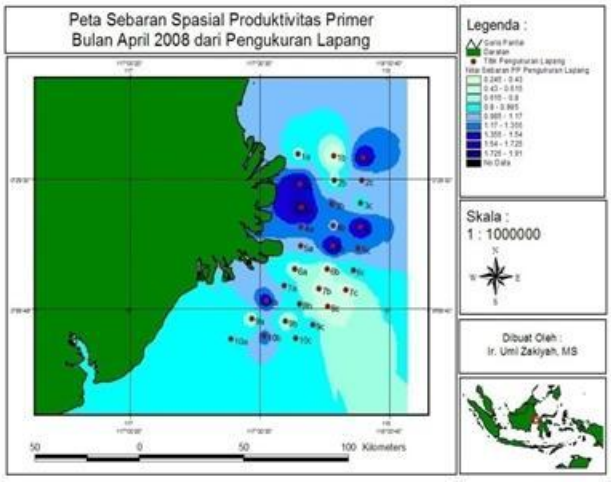


Figure 8. The Distribution Pattern of Primary Productivity in mg/L in Delta Mahakam Ecosystem based on *In situ* measurements within 30 Sampling Station on April 2008.

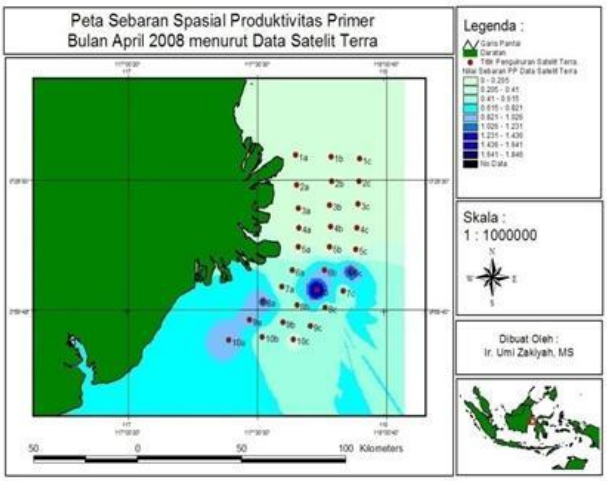


Figure 9. The Distribution Pattern of Primary Productivity in mg/L in Delta Mahakam Ecosystem based on derived Terra Image measurements within 30 Sampling Station on April 2008.

the primary productivity model applied for this area showed a high correlation, not only between the satellites data but also between the in situ measurements and the derived satellites data which count more than 70 percent. This high correlation showed there were relatively close correlation between the productivity and the parameter used in this model.

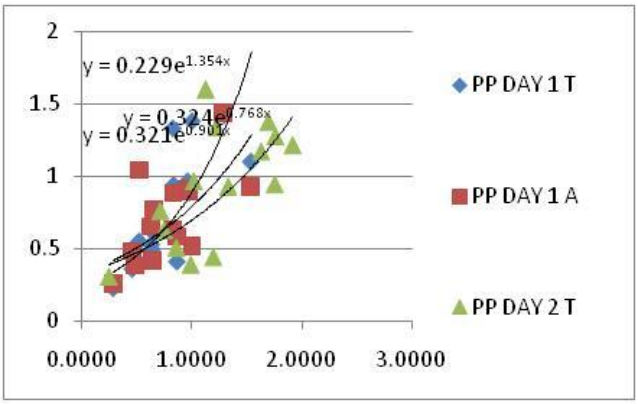


Figure 10 Graph showing the Values of Primary Productivity based on Derived Terra and Aqua Images of Day I and Day 2 Measurements. Value from Derived Terra Day 1 (Blue); Values from derived Aqua Images Day 1 (Red) and Values from Derived Aqua Images Day 2 (Green).

Thus this primary productivity value are capable to explain how would be the conditions of the environments in general. However not all of the variables measured would increase the primary productivity value, instead of increasing it to a certain level and start to decline again, shows that some parameter can becomes a limiting factor for the primary productivity of the environments.

4 Conclusions

Ecospatially, delta Mahakam is a very dynamic delta as it can be seen in the environmental factors measured. The condition of Chlorophyll a, temperature, sediment in the water will affect the level of the light penetration which in the end affect the IPAR or PAR conditions, one among important factor for the primary productivity, its level depend highly on their conditions. Based from the condition of the biotic, variables the thropic level of delta Mahakam ecosystem can be categorized as mesothropic which tend to oligothrophic or poor. This conditions can be explained clearly by other environmental conditions which were analyzed and concluded to be degraded enormously in every sectors. There was a relatively high correlation in the primary productivity model between the derived satellites data and the in situ measurements which count more than 70 percent. The correlation of the environmental variables and the primary production values shows to be significant as well. The ecospatial environment, basically affect the conditions of the primary productivity in general, however certain water quality parameter play as a limiting factors while other are not. These conditions explain that primary productivity model is a useful information in describing the level of environments in a certain space and time.

5 Suggestions

Research in environmental studies combined with remote sensing technology found to be useful to find relatively reliable information which can be used to manage the environmental problems through implementation of certain strategy of holistic management plan for environmental management. Research in the environmental (Abiotic, Biotic as well as Cultural) degradation would be more useful in complete in annual cycles as Indonesia has two main seasons which occurs annually. A global strategy and management plans are needed in solving the complex and global problems occurs in delta Mahakam ecosystem.

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