Monitoring the Impacts of Red Soil Runoff along the Matafa'a Mangrove Conservation Area in Samoa

T. Imo, F. Latū, A. Elisaia-Vaai, T. Arakaki, and M. A. Sheikh

***Abstract*—This study was conducted to investigate the impacts of red soil contamination in the mangrove area around Matafa'a Mangrove Conservation Area in Samoa. Ten soil samples were collected from December 2011 – August 2012 on the monthly basis. The pH, Fe, Olsen P and nitrogen (N) contents were determined. Results showed a significant level of Fe content (4.50-41.3 mg/kg), Olsen P (0.03-0.44 mg/L) and nitrogen (0.02-0.29 mg/L), while the pH ranged from 1.40 to 8.90. The results demonstrated that all sites are contaminated with acidic soil which is a common characteristic of red soil contamination which poses a threat to the health of coastal ecosystem including mangroves in Samoa.**

***Index Terms*—Environment, iron, nutrients, toxicity, red soil.**

I. Introduction

Mangrove and coral reef ecosystems provide crucial support to coastal life. In recent years the ecosystems face unprecedented pressure from climate change, coastal pollution and natural hazards such as Tsunami. The red soil pollution in the aquatic and coastal environment is a serious environmental problem that has attracted attention in field of environmental science. The lakes and rivers carry the eroded soils downstream, causing significant environmental and ecological problems. [1] reported that red soil contained 3.5–5% iron, mainly as Fe_2O_3, and is acidic in nature. Also river waters equilibrated with red soil have been reported to have pH values as low as 4.5 [1]. Every significant rainfall carries red soil easily to the coast, coloring the sea red. The phenomenon of red soil running off into coastal seawater is internationally termed "red soil pollution". Red soil pollution was recognized in the 1980's as responsible for causing significant damage to the growth of corals and fish in Okinawa, Japan [2]. The damage caused to the ocean, both in terms of its ecosystem and the scenery, is a major concern for some islands, including Okinawa [3]. The red soil contamination is often triggered by soil erosion, heavy rainfall, cyclones, land development and other artificial factors [4]. Sedimentation raises river beds and increases the severity of floods, which creates shoals and sandbars that make river navigation far more troublesome. The increased sediment load of rivers smothers fish eggs, causing lower hatch rates [5]. As the suspended particles reach the ocean, the water becomes cloudy, causing regional declines in coral reefs, and greatly affects coastal fisheries [6]. Coral reef and mangrove ecosystems play important role in ecosystem services such as ecological and protective values, renewable resource and as a source of food, medicine and income, but are most vulnerable to land based pollution including red soil. Numerous studies show that mangroves are subject to changes in freshwater flow (flow rate, nutrients, pollutants) and to marine influences (sea-level rise, salinity, acidity) [7].

Physico-chemical parameters such as Salinity have long been recognized as a controlling factor that determines the health and distribution of mangrove forests. Aqueous-phase, adsorbed and solid-phase forms of Al(III) are of critical importance in acidic soils [8]. Aluminum is a major problem in many acidic soils and the toxicity of Al^{3+} has been noted in several regions of the eastern United States, Canada and in the tropics where acidic soils are found [9]. In Samoa, red soil is found on high-lands for example surrounding Lake Lanuto'o[1]; along the coast of Matafa'a[2], Lefaga and inland areas such as Tanumalala and Moamoa. The Matafa'a village has pristine biodiversity resources and it is a mangrove Conservation Area under the Global Environment Facility (GEF). In Samoa, all mangrove areas, including Matafa'a mangrove conservation area have been gradually degraded due to environmental stresses both anthropogenic and natural. However, no systematic study has been carried out to assess the eco-toxicological impacts of such stresses including red soils on the mangrove and coastal areas in Samoa. This study therefore provides baseline information on the ecotoxicological impact of red soil on the coastal ecosystem of the Matafa'a mangrove conservation area.

II. Methodology

A. Study Site

This study was conducted at the Matafa'a Mangrove Conservation Area (Fig. 1) which is located on the coastal area southwest of the island of Upolu (14° 2′ 0″ South 171° 27′ 0″ West). In Samoa, the annual average temperature and rainfall are 28°C and 3000mm respectively (MNRE Report, 2005). Temperatures are coolest in July due to strong south-east trade winds [10]. Fig. 2 shows seasonal rainfall and temperature in Samoa [11].

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[1] Lake Lanoto'o Wetlands Of International Importance (Ramsar Convention)

[2] Located in the coastal area on the southwest of Upolu Island

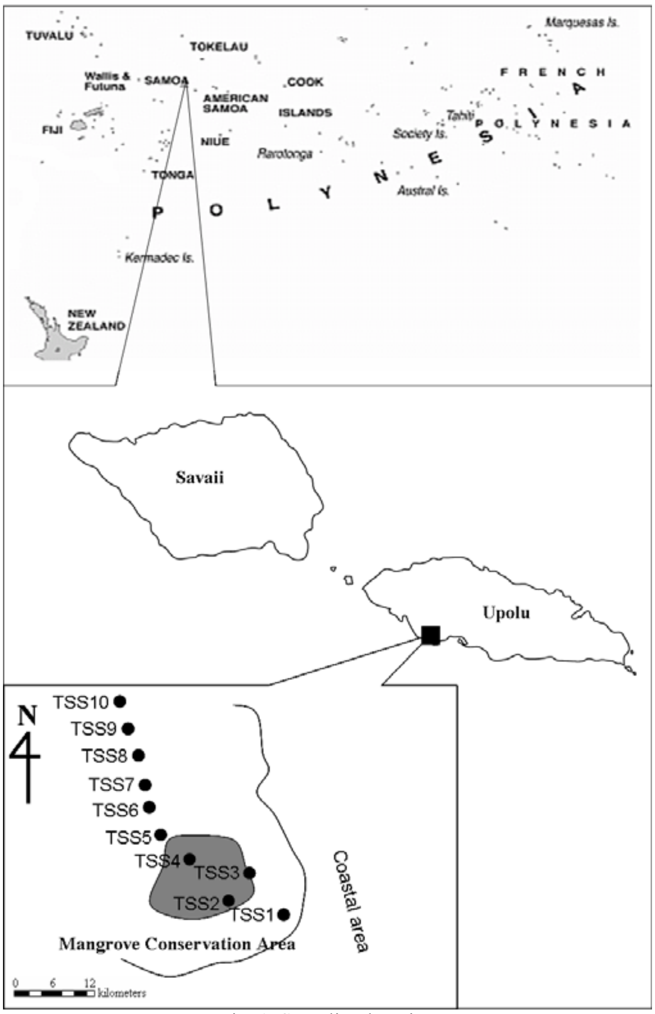

Fig. 1. Sampling location

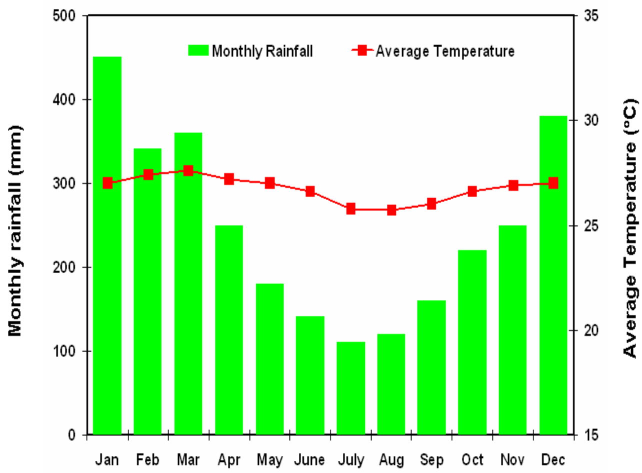

Fig. 2. Monthly rainfall and average temperature in Samoa

B. Sampling

Soil samples (15cm depth) were collected in a transect of (100m length with 10m intervals) along the Mangrove Conservation Area. The samples were collected monthly during wet season (November-April) and dry season (May-October) monthly. Details of sampling areas are shown in Table I.

C. Sample Preparation

Collected red soil samples were dried at room temperature to constant weight. Samples were ground and representative sub-samples can be taken even when small sample weights are taken for analysis. A <2mm-sized sieve sample was used for analyses.

D. Chemical Analysis

A 10g soil sample (air-dry <2mm) was weighted into a screw cap polypropylene centrifuge tube which contained two reagent blanks with each batch of samples. A 20mL of extracting reagent (DTPA) was added [12]. The sample was shaken for two hours on an end-over-end shaker to intensely extricate the sample in the extracting reagent. The solutions were centrifuge at 2000rpm for 15 minutes and filtered using Whatman No.1 filter paper to obtain a clear filtrate. The concentrations of iron (Fe) in the samples were determined directly in the filtrate within one day of extraction using Atomic Absorption Spectrometer (AAS – Perkin Elmer AAnalyst 200). For pH determination, a 10g of soil sample was weighed into a 50mL screw cap plastic bottle followed by addition of 50mL water. The bottles were capped and shaken well with end to end shaker for 1 hour. The samples were left still for 15 to 20 minutes. The pHs were measured with pH electrode calibrated with pH 7 buffer and set slope or sensitivity with the pH 4 buffer.

TABLE I: DETAILS OF SAMPLING AREAS

Transect	Depth (cm)	Physical properties	Location
TSS1	5-10	red-silt	mangrove
TSS2	5-10	red-silt	mangrove
TSS3	5-10	red-silt	mangrove
TSS4	10-15	red silt-clay	hillside
TSS5	10-15	red silt-clay	hillside
TSS6	10-15	red silt-clay	hillside
TSS7	15-20	red-brown silt-clay	hillside
TSS8	15-20	red-brown silt-clay	hillside
TSS9	15-20	red-brown silt-clay	hillside
TSS10	15-20	red-brown silt-clay	hillside

III. RESULTS AND DISCUSSION

A. Soil pH, Fe Content

Soil pH is one of the most important soil properties that affect the availability of nutrients, such as phosphorus and nitrogen. The results obtained from the pH and Fe analyses for the ten sampling months are shown in Fig. 3. The results revealed that the mean pH ranged from 3.53 to 6.36 and the mean Fe content ranged from 19.6 to 28.1 mg/kg respectively. The pH of the soil indicated that the soil was acidic. Soils with pH values ranging from 4.5 to 5.0 are classified as strongly acid in terms of soil reaction [13]. Soil pH is one of the most influential parameters controlling the conversion of metals from immobile solid phase forms to more mobile form [14]. There is a relationship between the pH of the soil and the iron content as shown by the increasing of the soil pH with decreasing of the Fe content as shown in Fig. 3. The highest Fe content was found in the month of February, which correlated with a slightly acidic pH and the lowest in the month of August (Fig. 2). The results indicated that the Fe concentration and pH at all sampling sites in all sampling months were extremely variable. A significant spatial pattern of red soil contamination is evident, which can be linked to soil erosion, heavy rainfall, cyclones, land development and other artificial factors.

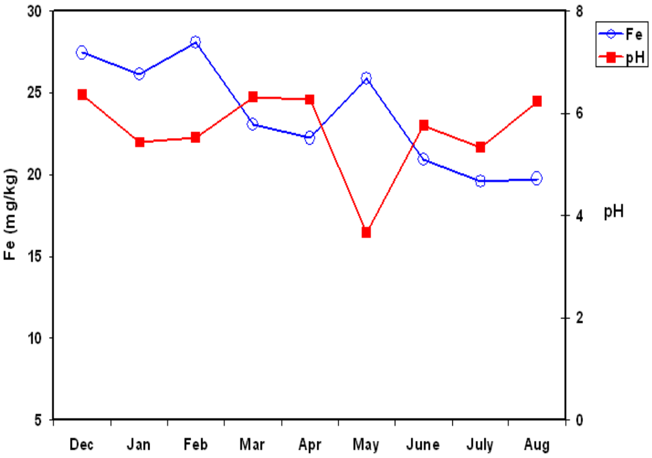

Fig. 3. Monthly means of pH and Fe content

B. Nitrogen, Olsen P

Generally, nitrogen is the growth limiting nutrient, which is needed in the highest concentration. Because of strong adsorption of phosphorus by variable-charge minerals such as iron (Fe) and aluminium (Al) oxides, utilization of soil and phosphorus in the red soils is generally <5-10% [15]. The means of nitrogen content in the soil ranged from 0.12 to 0.17mg/L respectively. The highest nitrogen content was found in the month of July as shown in Fig. 4. This could be due to the loss of soil from hillside during heavy rain, anthropogenic activities and natural causes. The means of Olsen P content in the soil ranged from 0.17 to 0.31mg/L. The results revealed that the Olsen P content in the soil increased significantly maybe due to previous agricultural application. [16] reported that the content of Olsen-P in soil is a main factor to estimate the ability of P supply from cropland or agricultural land.

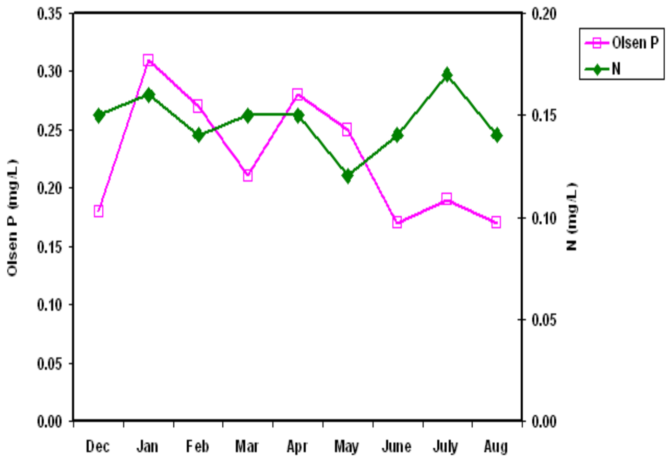

Fig. 4. Monthly means of nitrogen content and Olsen P

C. Spatial and Seasonal Variations

This study reports the monitoring data of red soil contamination in the conserved mangrove areas. The findings shows the three sites along the mangrove area have higher Fe content with acidic pH compared to other sites. This is due to the continuous influxes of Fe through both physical (sedimentation) and chemical (oxidation) processes [17]. The nitrogen and phosphorus content for all sites along the mangrove area depicts a decreasing trend compared to other sites. There is a correlation between the pH and the Fe content within the sampling months. The Fe content in the soil increases sharply as the soil pH decreases with a minimum pH range of 4.0 to 5.0. This indicates that the soil pH and the Fe content mainly affected the reaction activity in the soil. Fig. 5 shows the relationship of pH and Fe content in all transects. The acidic pH was shown in transect TSS1-TSS3 with high Fe content, this was compared with other transects which shows an increase in pH and decrease in Fe content significantly. The pH has a major influence on the availability of nutrients to plants [18] as in Fig. 6 shows a decreasing correlation between the phosphorus and nitrogen content. The highest phosphorus content was found in transects TSS1-TSS3, with the lowest content found in TSS10. Similar pattern shows in the nitrogen content. The highest nitrogen content was found in transects TSS1-TSS3 with the lowest content in TSS10. This indicates that nutrients are in excess in acidic soil compared to alkaline or high pH soil as shown in Fig. 7. Seasonal variation in soil available phosphorus has been recorded from a number of studies. A marked increase of phosphorus level was seen in the wet season and then a sudden declined in the dry season. This could be due to increased mineralization of soil organic phosphorus [18] and previous agricultural application.

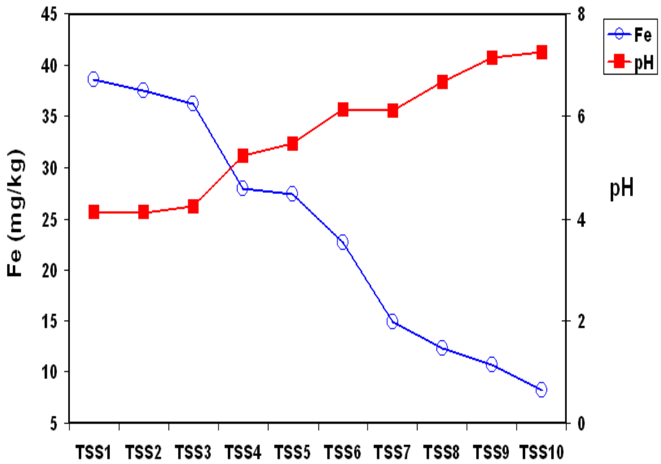

Fig. 5. Transect means of pH and Fe content

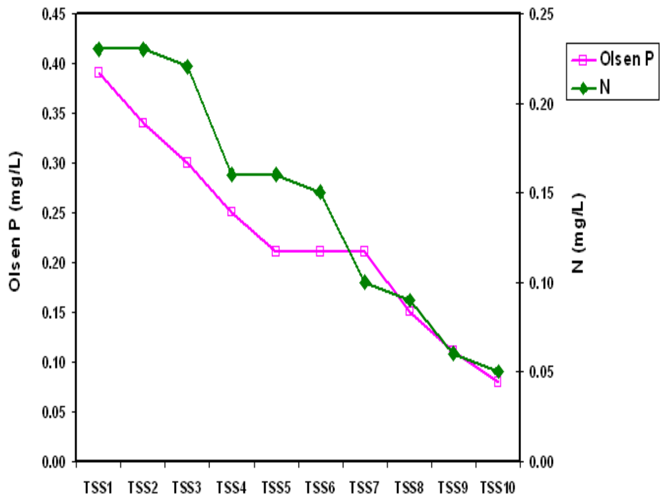

Fig. 6. Transect means of Olsen P and Nitrogen

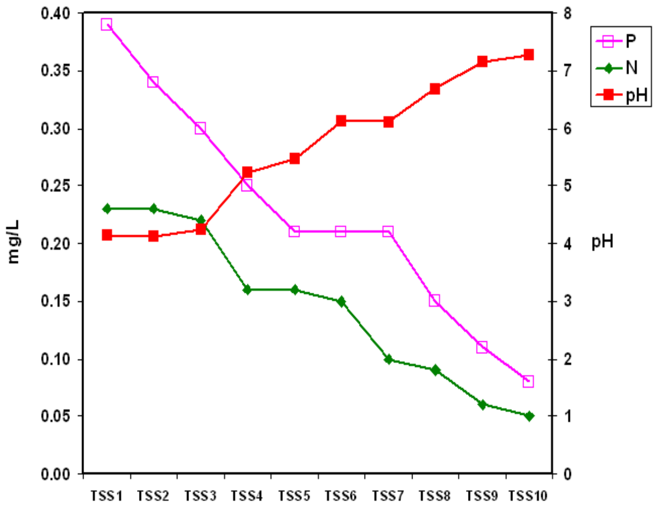

Fig. 7. Transect means of Olsen P and Nitrogen with pH

IV. Conclusion

This research provides important baseline data on impacts of red soil on mangrove ecosystems in Samoa. The levels of nutrients Fe content, Olsen P and nitrogen content are the fingerprint for contamination of red soil in the mangrove ecosystems. The results obtained from this study advocate for further studies regarding to the emerging threats to the vital coastal resources which have significant importance to the coastal societies, small Island States in particular.

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