Assessing the impacts of land use patterns on river water quality at catchment level: *A Case Study of Fuluasou River Catchment in Samoa*

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DEDICATION

To my parents

Tuimalatū Tovale Foemua Faiilagi Tuimalatū Vili Saili

& Leāmanaia Tuimalatu T. Faiilagi Saili

Abstract

A sound understanding of the impacts of land use on river water quality and their relationships is fundamental in addressing issues of water pollution at the catchment level. However, while the impacts of land use on water quality, at different scales of operation and management, are well researched in temperate climate region, there is limited information on the impacts of land use on water quality in most developing countries in tropical regions, including the Pacific islands. This study contributes to determining this information gap and qualifying these gaps through scientific evidence, as well as assessing the impacts of land use on river water in the Fuluasou River Catchment (FRC), Samoa. The FRC is one of the sub-catchments (and the largest of four) that drain Samoa's largest watershed basin known as the Apia Catchment Basin (ACB) on the island of Upolu. It covers an area of 45.57 km^2 dominated by forests on the higher elevation of the upland catchment, by agriculture (through mixed cropping e.g. taro and banana plantations with vegetable gardens) and tree crops plantations in the mid-catchment, and by home gardens with patches of small-scale plantations (taro & banana) around households in the lower catchment.

This study investigated the impacts of land use on river water quality response at ten sites across the upper, medium and the lower catchment. The study examined the relationships between various physicochemical (pH, temperature (Temp), turbidity (TUR), conductivity (COND), total dissolved solids (TDS), dissolved oxygen (DO), Nitrate (NO_3^-), total nitrogen (Total N), and total phosphorus (Total P), and microbiological (E. Coli & Total Coliform) water quality parameters, and four major land use types: agriculture (AG), grassland (GR) (ie. livestock), built-up areas (BUA) and forest (FO) cover in the catchment. A change in land use was estimated by comparing the land use maps created from the years 1999 and 2013. The water quality was sampled and measured every 2 weeks at ten sites over the three months of the dry season from August to October, 2013. The findings showed the mean (± sd) concentrations levels of Temp (27 ± 3.521), pH (8.4 ± 0.48), COND (124.2 ± 25.73), TDS (62.1 ± 12.88), DO 8.96 ± 0.558), TUR (1.3 ± 0.557), Total P (0.01 ± 0.0026), Total N (0.24 ± 0.0159), NO_3^-(0.01 ± 0.0032), T coli (9923 ± 1782), and E. coli (7431 ± 1347) respectively. The measured parameters were analyzed and compared with the WHO, SNDWS and DWSNZ/ANZECC drinking and aesthetic standards. All parameters were found to have had their total mean concentrations below the permissible standards, with the exception of Total coli and E.coli. Out of 53 water quality parameters that were tested and analyzed, all samples for Total coli and E. coli were significantly higher, and therefore failed to comply with the drinking

(SNDWS: 0/100 mL; WHO & DWSNZ/ANZECC: <1/100 mL) and aesthetic regulatory standards (DWSNZ/ANZECC: <260/100 mL) thus indicating a 100% of non-compliances.

The findings are indicative of high levels of microbiological contamination all across the catchment, which indicated very poor microbial water quality of the Fuluasou River. The Total coli and E. coli were recognized as the two major pollutants in the Fuluasou River. The coefficient of variance (CV) for all the measured parameters have indicated a low variation amongst the measured parameters across the upper, mid and the lower catchment at different sampling stations, except TUR (44.4%), NO_3^- (38.9%) and TSS (37%) with a significant degree of variability compared to other parameters.

The land use change analysis from the years 1999 and 2013 informed 12.7% of forest (FO) had been lost since 1999, with AG lands increasing by 10.8%, GR slightly decreased by 0.50%, and with BUA increasing by 2.40%. The findings demonstrate that FRC is under threat from increasing land clearance for agriculture activities such as mixed cropping (eg. taro and banana plantations), tree crops plantation (eg. coconut), and increasing in BUA to allow expansion for new developments (e.g. settlements) especially on the eastern-upper & mid to lower catchment. The study found a strong positive relationship between the four main land use types and water quality parameters. In the upper catchment where high proportion (%) of FO exists and this was found to be strongly associated with decreasing concentration levels of Temp, pH, COND, TDS, Total N and NO_3^-. This is unlikely the mid-catchment where AG is the dominant land use type and it positively influences pH, Temp, COND, NO_3^-, TDS, Total N, Total P, which are indicative of high intensity in mixed-cropping plantations and possible waste input from increasing agricultural activities and settlements going downstream. This spatial relationship is similar to GR areas used for livestock grazing and cattle farming in the upper and the mid-catchment which is strongly reflected in increase in pH, COD, TDS, NO_3^-, E.coli, Temp, Total N, Total coli, and E.coli. Despite having water quality parameters that are strongly influenced by land use across the catchment, individual effects for each land use type could not be determined due to a multicollinearity issue, as a result of the net effects of land use proportions (%) of sub-catchments delineated upstream. This can be further examined in future studies. Future improvements to the assessment of land use impact, can include water quality monitoring covering the wet seasons (Nov-Apr), as more runoff could possibly discharge higher concentration levels of pollution, instead of only having samples from the dry period.

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Abbreviations

ACB	Apia Catchment Basin
ADB	Asian Development Bank
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
COD	Conductivity
CV	Coefficient of variation
DO	Dissolved Oxygen
DWSNZ	Drinking Water Standard for New Zealand
EPC	Electric Power Corporation
EU	European Union
FAO	Food Agricultural Organisation
FRC	Fuluasou River Catchment
FWMP	Fuluasou Watershed Management Plan
GPS	Global Positioning System
ISSO	International Student Services Office, Massey University
JR	Name of Water Treatment Plant
LMEM	Linear Mixed-Effect Model
MNRE	Ministry of Natural Resources and Environment
MoH	Ministry of Health
PoAs	Plan of Actions
SNDWS	Samoa National Drinking Water Standards
SOP	Standard Operation Procedures
SPREP	South Pacific Environment Programme
SROS	Scientific Research Organisation of Samoa
STEC	Samoa Trust Estates
SWA	Samoa Water Authority
TDS	Total Dissolved Solids

TUR	Turbidity
TEMP	Temperature
UNDP	United Nation Development Programme
WRD	Water Resource Division, MNRE
WTP	Water Treatment Plant
WHO	World Health Organisation