PERSPECTIVES PAPER

Global Water Partnership Caribbean

IMPACT OF LAND USE CHANGE ON WATER RESOURCES, AVAILABILITY AND WATER QUALITY IN SAINT LUCIA

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This Perspectives Paper was prepared by Miguel Montoute and Dr. Arpita Mandal. It is intended to galvanise discussion within the GWP-C network and the larger water and development community.

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ABOUT GLOBAL WATER PARTNERSHIP-CARIBBEAN

The vision of the Global Water Partnership-Caribbean (GWP-C) is for a water secure Caribbean. Our mission is to support Caribbean countries in the sustainable management of their water resources at the community, national and regional level.

GWP-C is 1 of 13 Regional Water Partnerships of the Global Water Partnership (GWP).
It was established in 2004 to foster the application of Integrated Water Resources Management (IWRM) in the Caribbean region. IWRM is the coordinated development and management of water, land, and related resources, in order to maximise economic and social welfare without compromising the sustainability of ecosystems and the environment.

Any organisation with an interest in water sustainability in the region, can become a GWP-C Partner. GWP-C currently has over 100 partners in more than 20 Caribbean countries. These include water management agencies, water user associations, private water management agencies, government institutions, academic and research institutions, private sector companies, non-governmental organisations, community-based organisations, civil society organisations, youth organisations, regional agencies, consultancy firms, among others.

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Global Water Partnership
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1. INTRODUCTION

This perspectives paper delves into water resource matters that arise from land use activities and changes within watersheds in Saint Lucia, which have commonalities with other Small Island Developing States (SIDS) within and beyond the Caribbean Region. Unregulated land use changes impact water quality and quantity which may not only adversely impact water service provision but ecosystem services. The paper covers pertinent issues such as land tenure issues; impact of agriculture and tourism sectors on the water sector; wastewater management and policy gaps, as a means of conducting a country specific situational perspective of land use/cover change impacts on freshwater resources.

Land use change has been regarded as arguably the most pervasive socioeconomic force driving the degradation of watershed ecosystems, with the transition from undisturbed natural habitats to agriculture or urban development (Langpap et. al., 2008). It is therefore important that land use policy and planning have a significant bearing on the natural resource condition of native forests, soil and water, although it can take decades to fully manifest the associated impacts (Hicks, 2018).

Urbanization leads to increased waste production in quantities beyond what the natural environment can absorb; our expanding cities therefore have a tendency to compromise water quality through pollution and land use changes (Boberg, 2005). There is also the threat of over extraction because of increases in water demand for industry (Boberg, 2005) and tourism. Groundwater and surface water quality can also be contaminated from poor urban and farm wastewater management. Concerns regarding the contamination of some natural springs from faecal coliforms have been raised in Saint Lucia. This is due to their proximity to residential and farming activities.

Agriculture is a leading cause of surface water impairment (Langpap et. al., 2008) with horticulture and intensive animal farming being of particular great concern (Boberg, 2005) due to impacts from agrochemicals and farm waste, which lead to increases in nutrient loads, surges in algae growth and fluctuations in dissolved oxygen (Langpap et. al., 2008). Agricultural production also requires significant quantities of water, with a global consumption of at least 70% of total freshwater resources, which is expected to increase with more forest conversion to agricultural land (Pimentel et. al., 2004). Erosion due to land degradation adversely affects agriculture by reducing water availability. This is because eroded soils absorb about 87 percent less water than their non-eroded soils (Pimentel et. al., 2004). They therefore retain less moisture and generally require higher water usage through more frequent irrigation for crop cultivation.

We cannot manage water if we cannot manage land; therefore, ineffective land management precludes the proper management of water resources which has many cross cutting issues, spanning various socio-economic sectors. Water is not only vital for ensuring safe water, sanitation and hygiene (WASH) for health but is also required for the economic viability of nation states. In the Caribbean, water is vital for sustaining agricultural production, touristic enterprises, commerce and manufacturing.

This life sustaining substance is inextricably connected to the quality of our daily lives but its true economic value may be obscured by the lack of proper economic valuations.

Since water is intricately connected to land, it is imperative that we respond in an adaptive and integrated manner. This requires planning which incorporates flexible, practical, measures for proper land management as a means of protecting water resources. This adaptive, integrated approach is required for dealing with the uncertainty and complexity involved in ensuring that water is managed sustainably from the "ridge to the reef" for the benefit of all. Land management in the Caribbean region has posed challenges revolving around the competing ideas of improving economic efficiency and productivity; increasing access to marginalized groups; and providing land and water to successive generations through sustainable practices (Williams, 2003). It is important that we find a creative way of marrying these ideas into policy, planning and programme implementation through a balanced approach.

2. GEOGRAPHICAL OVERVIEW OF SAINT LUCIA AND ITS WATER RESOURCES

Saint Lucia is located at latitude 13°59'N and longitude 60°59'W within the Lesser Antilles, with an area of approximately 620 km2 (FAO, 2015). Surface water is the primary source of water resource for the island which flows in a radiating pattern from the central highlands towards the coast following the topography of the island. The island is primarily composed of volcanic rocks with minimum to nil permeability which thus accounts for the surface water drainage pattern. The island is divided into 37 watersheds (see Figure 1 and Table 1) which comprise the bulk of its water supply for the island. The drainage channels are perennial following deep cut valleys towards the Atlantic Ocean to the East and Caribbean Sea to the West. However, there are some watersheds with natural springs, such as Marquis and Soufriere which partially supply water for potable water production, to the Water and Sewerage Company (WASCO), the island's sole water utility. Although there has been interest in greater exploration of groundwater sources in the past, it has been reported that its contribution to the overall water supply would be miniscule for direct confined aquifer abstraction with the exception of small rural communities (FAO, 2015) and small agricultural, industrial and tourism enterprises. However, further research is required to thoroughly quantify and inventorize the extent and viability of groundwater resources and aquifers in Saint Lucia.

The most important rivers for water supply are Cul de Sac, Canelles, Dennery, Fond, Piaye, Doree, Canaries, Roseau, and Marquis (See Appendix 1) (FAO, 2015). It should be noted that river flows drastically increase during the wet season, from June to November but potable water intermittency may occur due to heavy siltation and clogging of water intakes. Streamflow reductions from surface sources downstream of WASCO water intakes have been noted and are partially due to increased water abstraction by the water utility over the years. This has been especially evident during the dry season (FAO, 2015) which reduces the remaining streamflow available for farmers and recreational users downstream. This is further exacerbated by soil and chemical contamination (CEHI, 2008) resulting from unsustainable land use, which may happen year round. Trends in flow reductions above WASCO intakes are primarily due to reduced rainfall from climate change/variability, deforestation and land degradation.

The annual average long-term rainfall is about 2300 mm which ranges from about 1265 mm/year along the coast to approximately 3420 mm/year within the mountainous interior (See Appendix 2 and Appendix 3); with total renewable water resources estimated at about, 300 million m3/year (FAO, 2015). It should also be noted that Saint Lucia's only major dam, the John Compton Dam, located in the Roseau Watershed has a design capacity of about 3 million m3 (FAO, 2015; WASCO, 2013) which was reduced to 1.9 million m3 in 2013 (WASCO, 2013) primarily due to siltation from eroded sediments. A series of smaller water intakes are scattered throughout the island for augmenting water supply and as previously mentioned, downstream surface streamflow had been decreasing possibly due to increased water abstraction volumes by the water utility. In 2010 it was estimated that the production capacity of the island's waterworks was about 26.4 million m3/year (FAO, 2015).

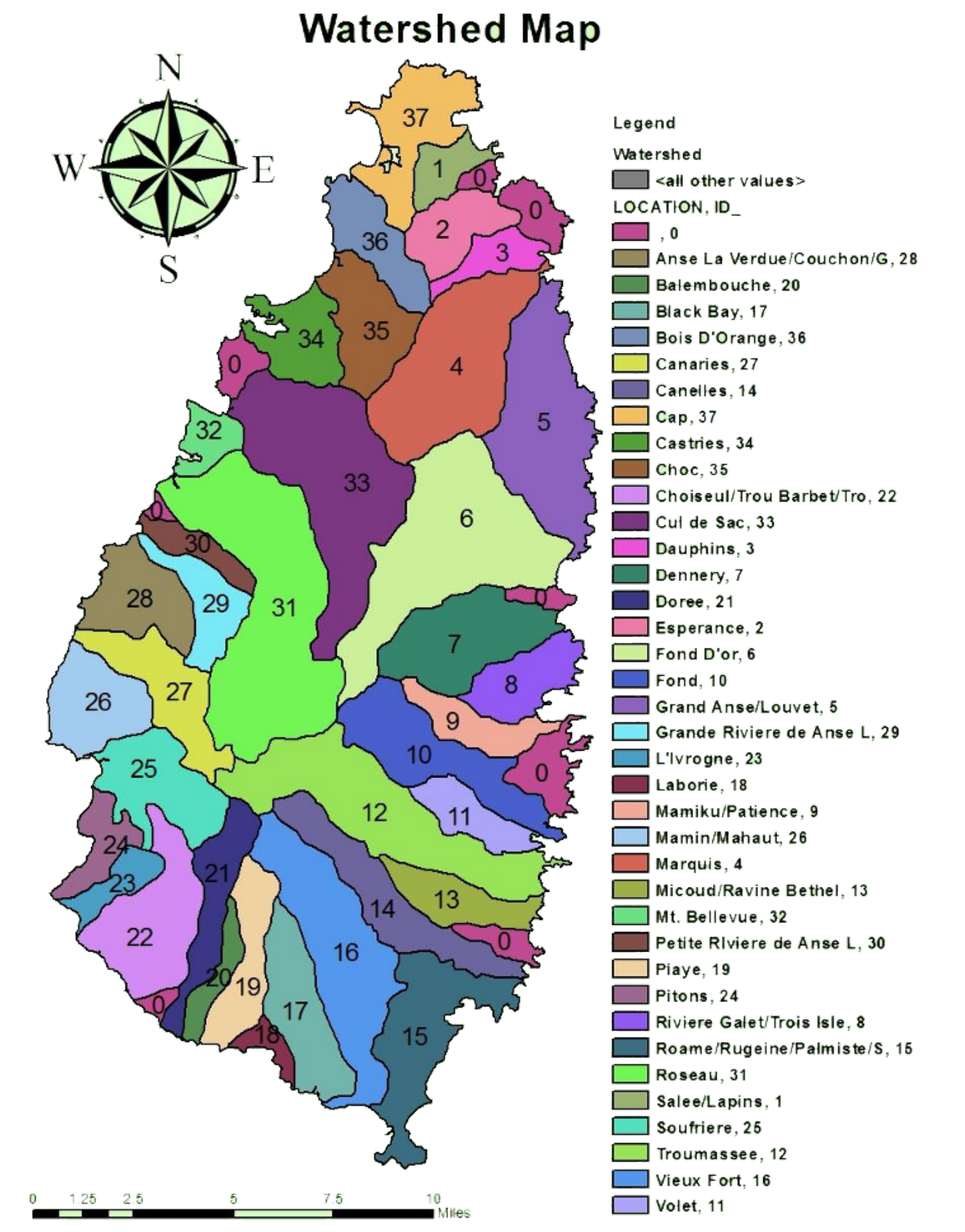


Figure 1: Watersheds of Saint Lucia [Source: Government of Saint Lucia-Water Resource Management Agency (WRMA)].

Top 5 watersheds in terms of size (ranked in descending order of size)	Size (km^2)	Top 5 watersheds in terms of dry season streamflows (ranked in descending order of streamflows)	Estimated average dry season streamflows (l/s)
Roseau	48.19	Roseau	733
Fond D'or	40.52	Troumassee	498
Cul de Sac	39.20	Cul de Sac	297
Vieux Fort	31.47	Soufriere	246
Marquis	30.64	Vieux Fort	238

Table 1: Top five watersheds ranked in terms of size and estimated streamflows (Government of Saint Lucia, 2012).

Figure 2 below shows comparative trends (from 1982 to 2015) in potable water production, consumption and water loss/wastage volumes as reported by WASCO. The trend shows a steady increase in production over the years, with consumption fluctuating around the estimated average annual demand of about 8.4 million cubic meters as reported in 2013 (WASCO, 2013), which is expected to have increased by 2020. It is interesting to note that according to Saint Lucia's Sectoral Adaptation Strategy and Action Plan (SASAP) for the water sector, there is an estimated national potable water supply deficit of 35 percent, and non-revenue water (NRW) of at least 42 percent (Government of Saint Lucia, 2018a). Datasets from The Central Statistical Office of Saint Lucia show that water losses have been as high as 52 percent.

In terms of disaggregation by sectors, Figure 3 shows relative consumption for the boating, commercial, domestic, hotel and government sectors from 2012 to 2019 with domestic consumption about 57 percent, hotels 17 percent, commercial 13 percent and government 12 percent (Government of Saint Lucia, 2018a). It should be noted that WASCO's operational focus does not include the supply of raw water to farmers (as they generally abstract directly from rivers), notwithstanding, figures regarding water withdrawal for 2007 show a total of estimated withdrawal of about 42.9 million m3, with 71 percent towards irrigation and 29 percent towards the various municipalities (FAO, 2015).

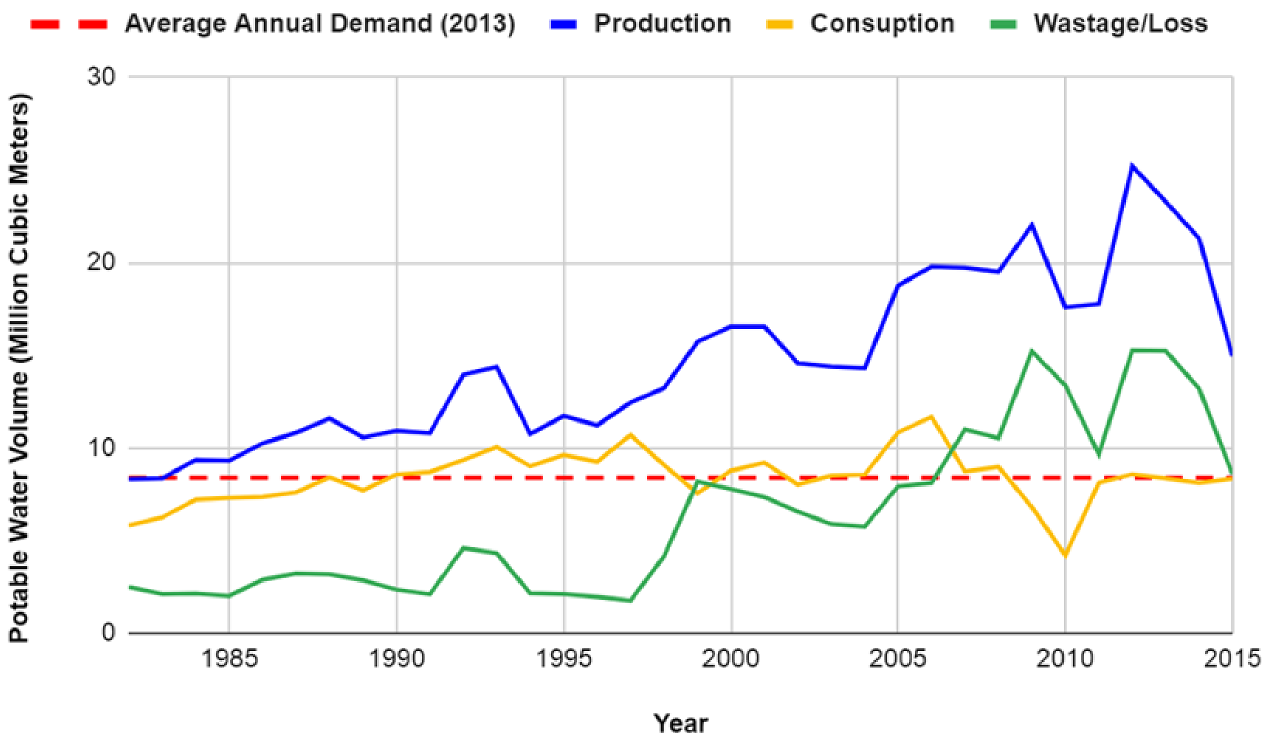


Figure 2: Estimated[1] national annual water demand, production, consumption and wastage/loss from WASCO [(data sourced from The Central Statistical Office of Saint Lucia and WASCO (2013)].

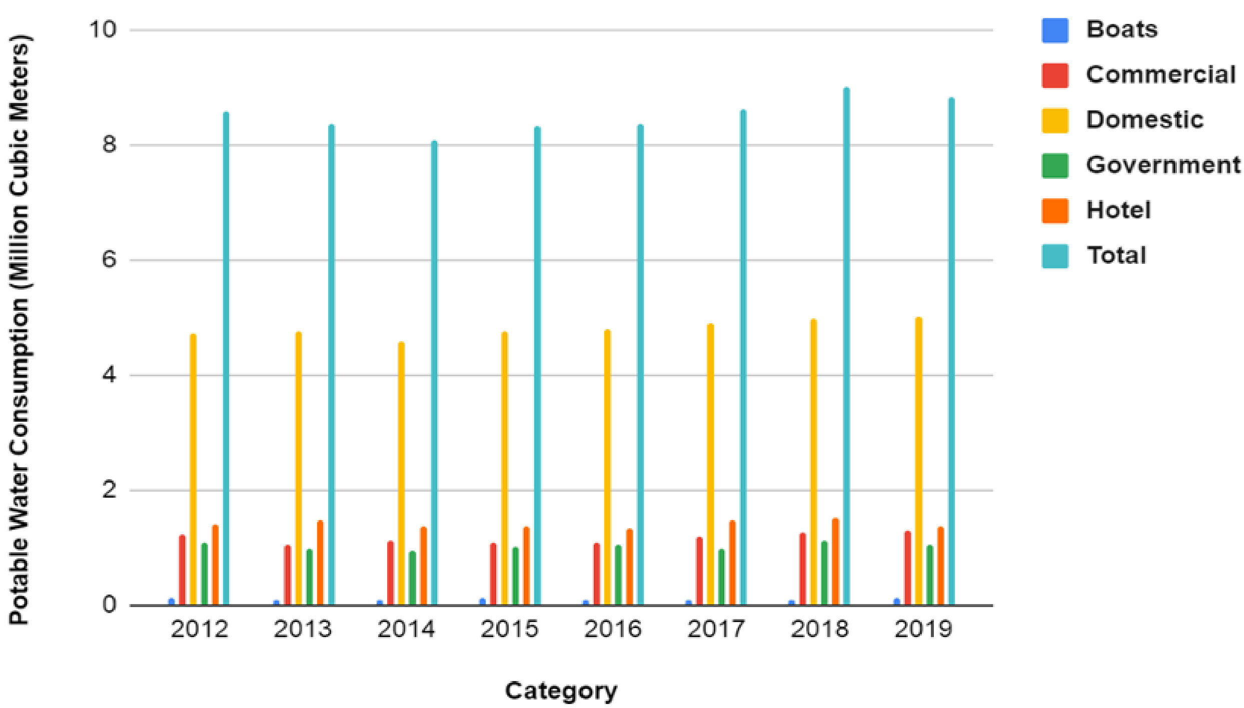


Figure 3: Potable water consumption from various sectors in Saint Lucia (data sourced from The Central Statistical Office of Saint Lucia).

[1] According to metadata from The Central Statistical Office of Saint Lucia, unaccounted for water according to the World Bank was 52% and 47% in 1999 and 2000 respectively. In 2003, accounts that were inactive and duplicated were deleted from the system. In 2006, the meter for Theobalds Treatment Plant was faulty. In 2010, the drought spell and Hurricane Tomas (in October, 2010) left the meter for Canaries faulty for the year.

3. LAND TENURE IMPACTS ON WATER RESOURCES

The Saint Lucian context, a product of a mixed French and British colonial heritage (OAS, 1986), reflects the barriers which regional land and water resource managers face. The main land ownership types recognised on the island are individual ownership; tenants in common and undivided; family land and crown land.

The family land system is a land tenure characteristic which Saint Lucia shares with other Caribbean territories, with at least 38.3 percent of all land falling into this category between 1986 and 2004 and exhibiting little change in percentage holdings over those years (Bloch et. al., 2005). This system has its roots in the former plantation based economy through which land acquired by former slaves was passed down through generations (Vargas and Stanfield, 2003). The last national agricultural census conducted in Saint Lucia in 2007, showed a decline (60 percent to 40 percent) in the share of individually owned land in total land holdings as compared with the previous 20 years and an increase in family land from 24 percent to 42 percent (Government of Saint Lucia, 2007). This family tenure system was characterized by a combination of poor quality, overused, fragile, small parcels held by a significant number of farmers and underutilized highly productive plantation lands (Government of Saint Lucia, 2007).

Historically it seems that land titling programmes have not significantly impacted formal land transaction activity over time as exemplified by the low rate of conversion of family land towards private ownership. Individuals have failed to register inheritances and leases through official state regulatory channels (Griffith-Charles, 2004). Although Saint Lucia had achieved 100 percent registration and mapping under its titling and registration programme, information can be out-dated and informal forms of land tenure re-emerge due to a failure to register deaths and inheritances (Griffith-Charles, 2010). Also, the prevention of squatting which in part drives unsustainable land use activities on private and public land has been a challenge due to the lack of sufficiently robust and balanced physical planning legislation (Government of Saint Lucia, 2016b). Physical planning legislation which fails to effectively regulate squatting emboldens squatters and disincentivizes them from engaging in best practices which reduce land degradation and subsequent source water impairment.

Also, direct land acquisition programmes for establishing forestry reserves or watershed protected areas may prove more difficult for family lands located in environmentally sensitive areas. This is due to the uncertainties regarding ownership inherent in this informal system. These property acquisition programmes have been shown to be effective at improving watershed health (Langpap et. al., 2008) and water quality especially when they are acquired upstream of critical water sources.

4. LAND USES AND CHANGES

4.1 Agriculture: crop and livestock production

Land use activities create products or benefits for users (Government of Saint Lucia, 2007) which may be agricultural, commercial or infrastructural in nature. From 1996 to 2007 the national agricultural census showed a seeming abandonment of banana plots which led to a decrease in land used for permanent/medium term crops, while land used for temporary crops had increased (Government of Saint Lucia, 2007). This has been reflected by the reduction in banana crop production over time. Farmers have sought more opportunities in other more temporary/short-term cash crops such as ground provisions (e.g. dasheen and tania), which should be intercropped to reduce soil erosion, especially on converted banana farms with degraded soils.

Roughly only 28 percent of the total land is regarded as appropriate for agriculture due to topographical restrictions. In 2012, at least 10 600 ha was under some form of agricultural use (crop production, meadows and pastures) (FAO, 2015) Figure 4 shows the various land cover classes on the island in terms of their percentage coverage and Figure 5 includes changes in agricultural land use for 2000 and 2009. It should be noted that the impact of unsustainable crop production on water resources can be detrimental. Indiscriminate forest clearance practices for crop tillage above water catchments and water intakes pose risks of land slippage and increased sediment load of rivers. Ironically, this leads to high water intermittency during the wet season even though higher river flows should augment supplies. High intensity rainfall events cause high runoff which erodes deforested fragile soils, hence leading to water intake clogging from high silt accumulation.

Mitigative techniques such as check dams, bench terracing, vegetative strips/grass barriers and hillside ditches along contour lines have been recommended (Government of Saint Lucia, 2018b) and are necessary to retard and trap silt above important water catchments. Interventions have occurred in the Roseau Watershed through the implementation of forestry restoration works by means of a collaboration between WASCO and the Forestry Division of the ministry responsible for agriculture and natural resources; this has facilitated the reforestation of lands which were degraded above the dam. Under the Integrating Water, Land and Ecosystems Management in Caribbean Small Island Developing States Project (IWEco), similar reforestation works were being undertaken in the upper reaches of the Soufriere Watershed as a means of restoring degraded sites, headwaters and agricultural areas (GEF, 2016). Also of significance is the proper regulation of agrochemicals (fertilizers and pesticides) which seep into groundwater and pose a risk of contamination of natural springs and rivers which may receive contaminated base flows.

There has been increased interest in livestock production, specifically poultry and pigs (Government of Saint Lucia, 2007). For a variety of reasons family land is prone to unlawful squatting, which has adversely contributed to land degradation through unsustainable practices, such as unrestricted livestock grazing and unregulated piggeries.

However, these activities also occur on private lands (GEF, 2007) which often fall out of the jurisdiction of state regulation due to the absence of a national land zoning plan and zoning regulations. Point sources of water pollution which compromise the quality of fresh and marine waters sometimes arise from poor wastewater management practices on these farms.

Piggeries are of particular concern because of the high risk (see Figure 6 and Figure 7) of contamination from faecal coliforms, especially if they are located near river banks and above water intakes. A river assessment within the Fond D'or Watershed regarded faecal contamination from households and piggeries as a major problem (Serville, 2009). Many piggeries were identified along the banks of the Fond D'or River and its tributaries which served as channels for effluent discharge, leading to E.coli counts ranging between 10384 and 86200 CFU/100ml (see Figure 7), which exceeds the maximum acceptable limit of 20 CFU/100 (as specified by Saint Lucia's Guidelines for Recreational Water Quality (SLBS, 2010). The rocky terrain in the area was also observed to be unsuitable for wastewater absorption, hence leading to increased effluent runoff of farm and domestic effluent into rivers and streams.

As pristine forested lands where water intakes were originally constructed open up to unregulated agricultural use, water catchments will be exposed and vulnerable to pollution as seen in Figure 8 of the Marquis Watershed where two water intakes are located within areas recognized as mixed farming and build-up residential/commercial areas. It should be noted that this is a traditionally agricultural, rural watershed that is experiencing urban creep due to its proximity to the more economically vibrant urban/suburban areas in and around Castries City and Rodney Bay, which have higher rents.

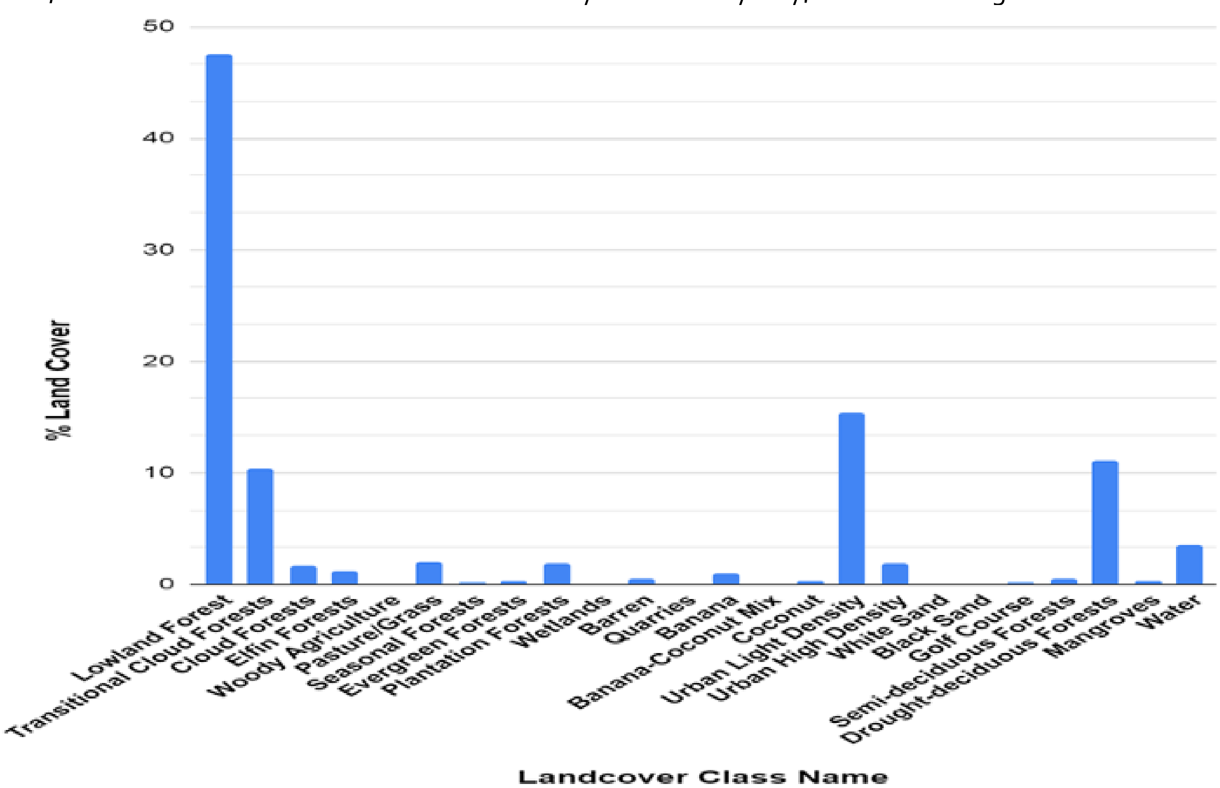


Figure 4: Land cover classes in Saint Lucia (based on 2005 data, sourced from The Central Statistical Office of Saint Lucia).

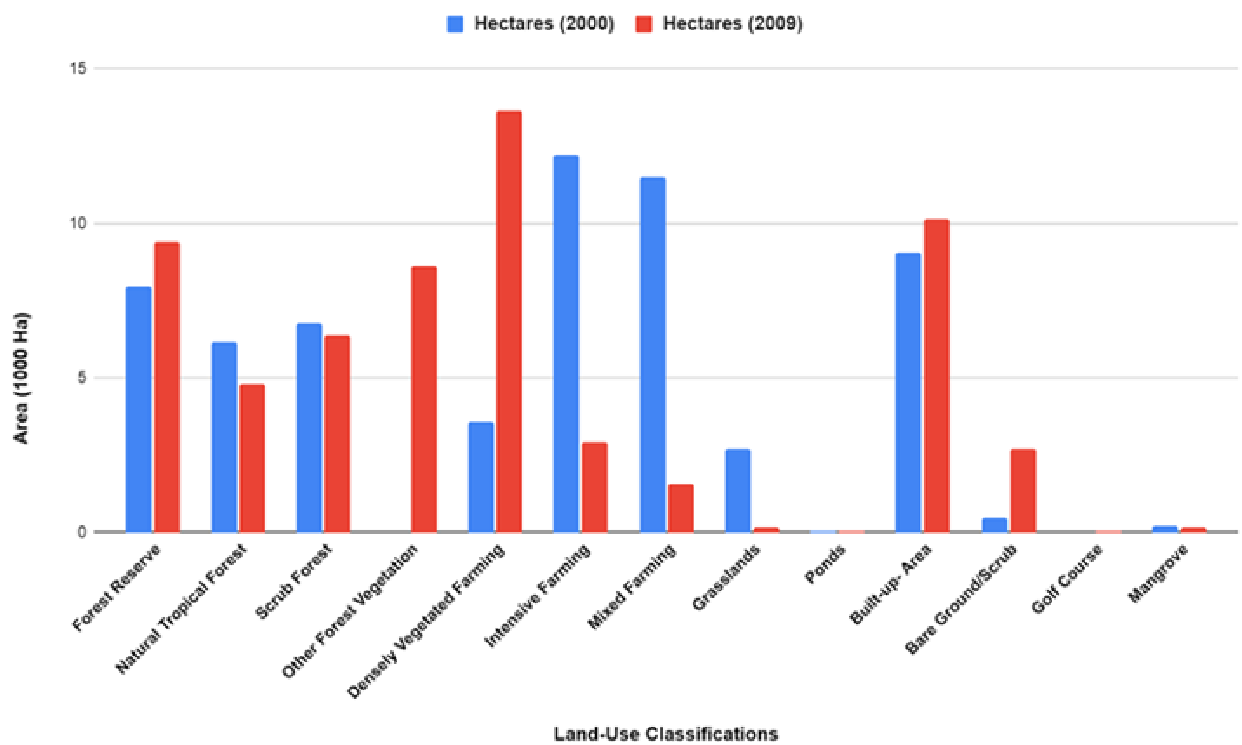
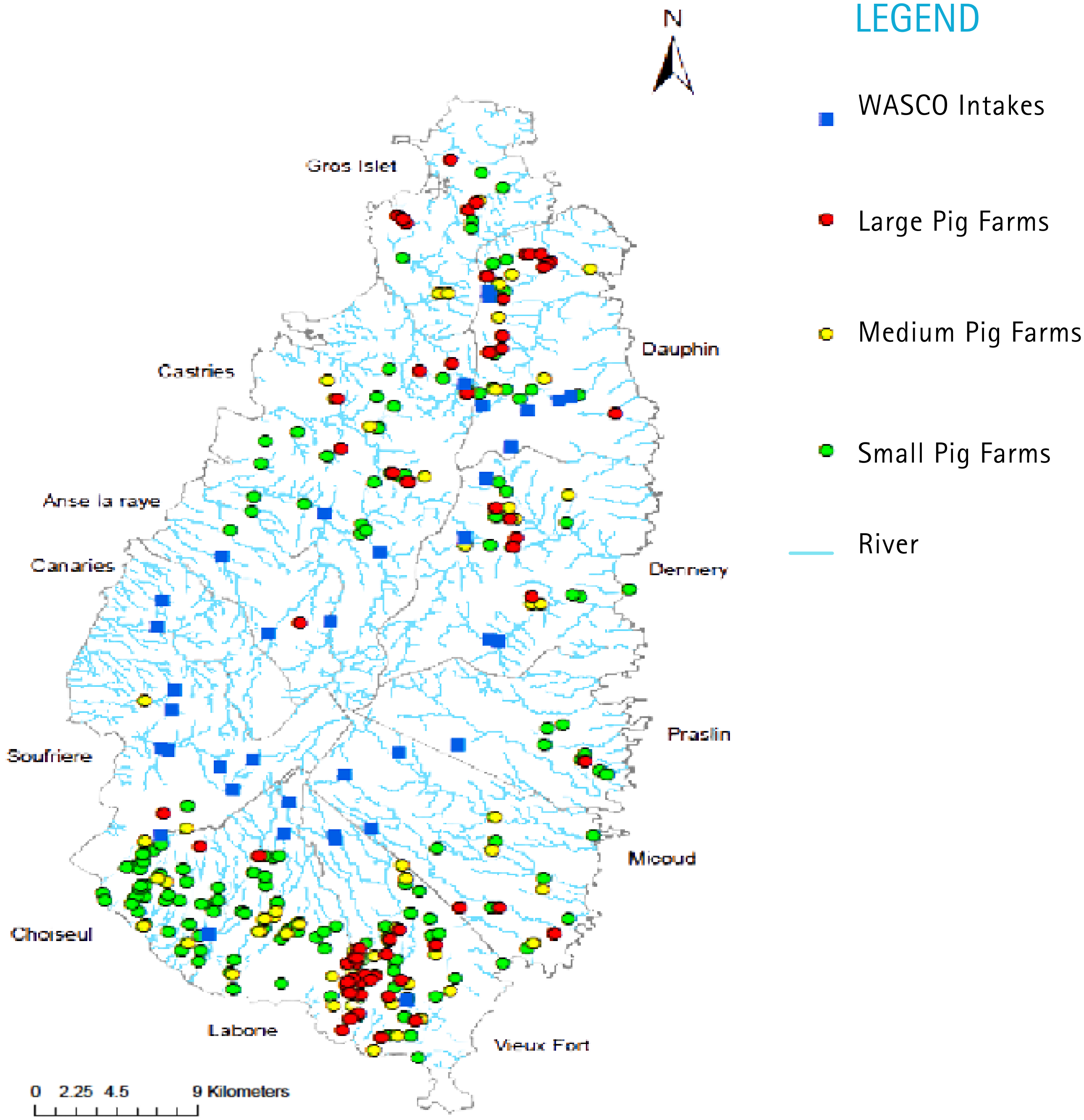


Figure 5: Land use changes between 2000 and 2009 (data sourced from The Central Statistical Office of Saint Lucia).



Pen Size	
Small	Less than 20 Pigs
Medium	20 - 50 Pigs
Large	50 or more Pigs

Figure 6: Map[2] which shows the proximity of piggeries to water utility intakes (Government of Saint Lucia, 2017b).

[2] Prepared by ECOPSIS from 2014 census data for Background Paper for the National Policy on Wastewater Management (in Saint Lucia), under the Disaster Vulnerability Reduction Project (DVRP)

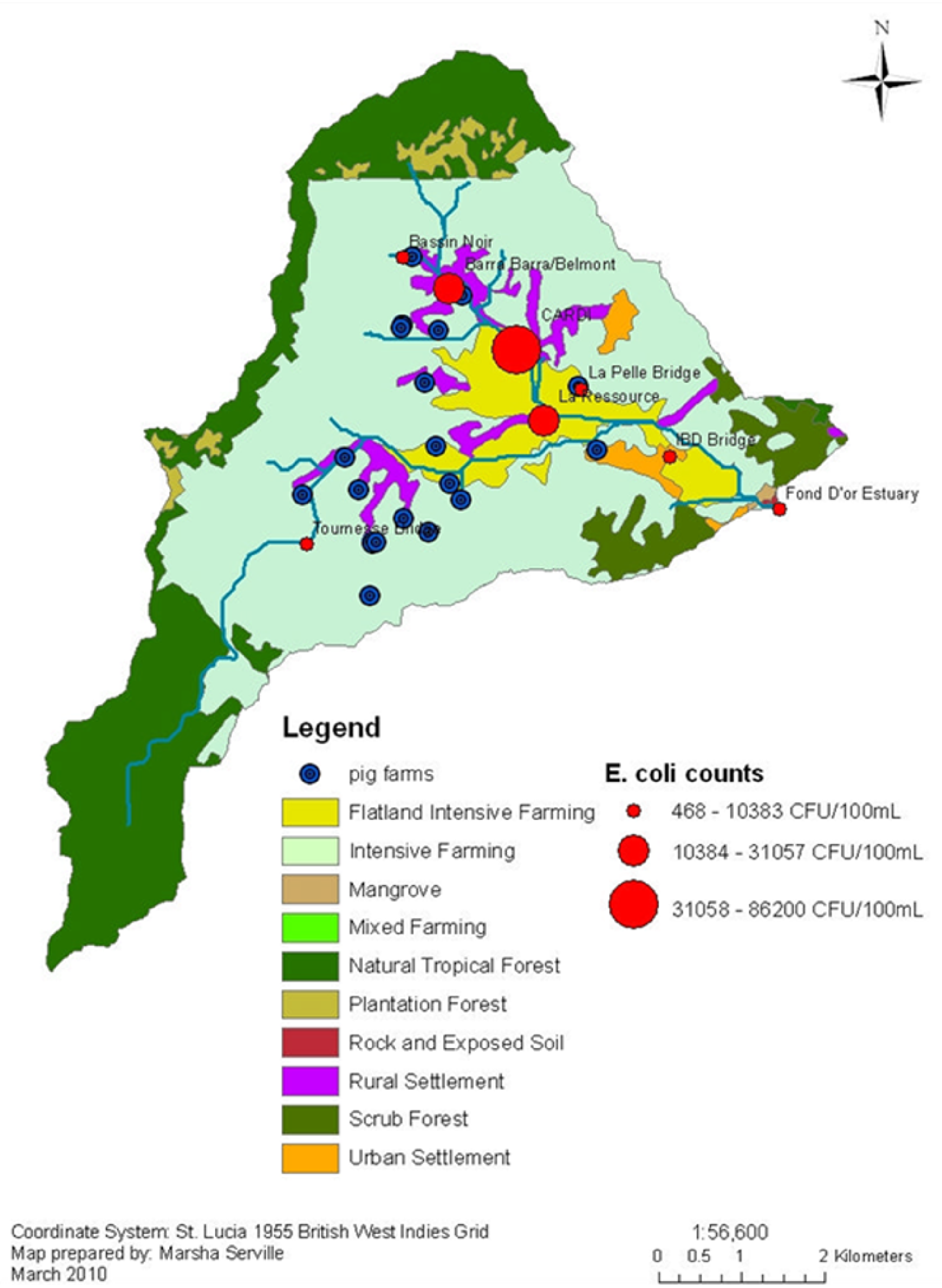


Figure 7: E.coli counts at various locations along the Fond D'or River in Saint Lucia (Serville, 2009).

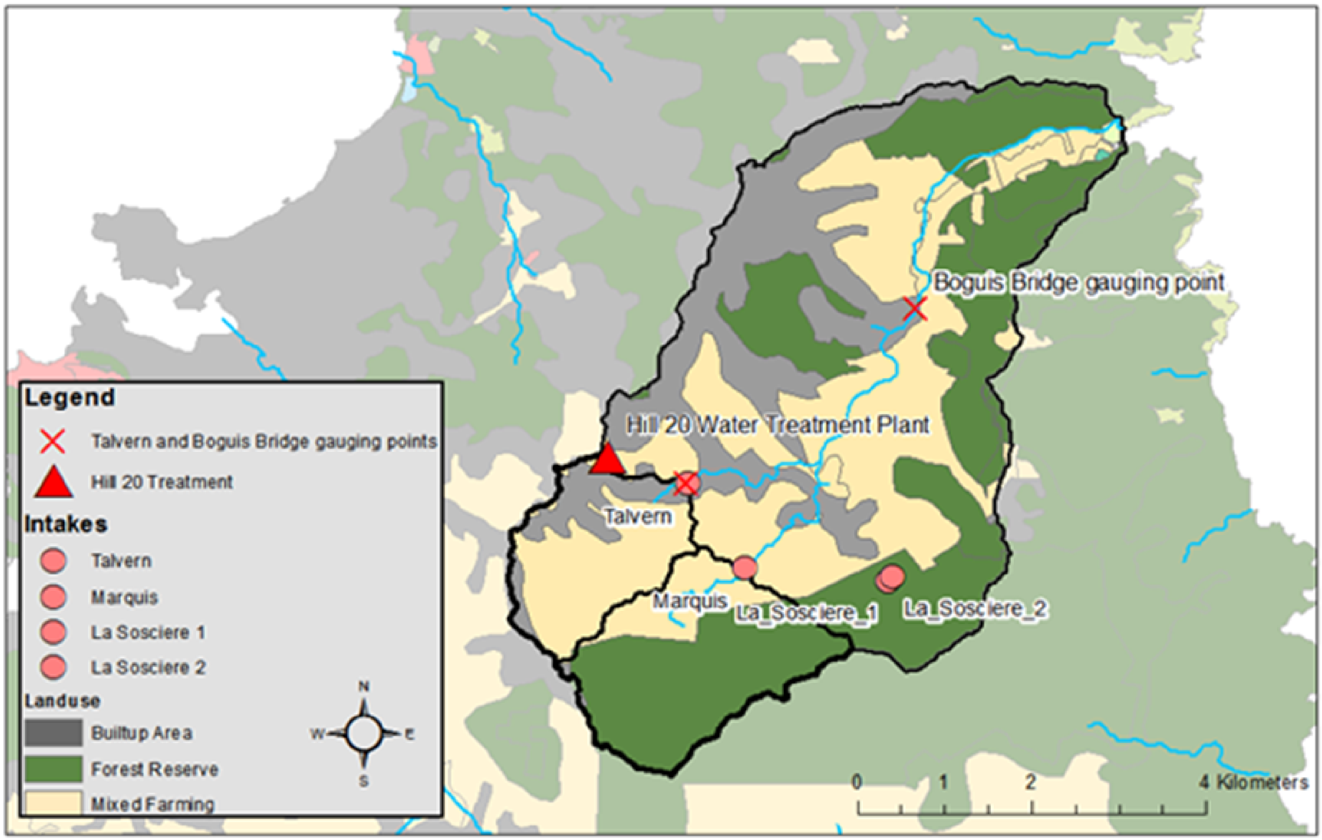


Figure 8: Map of the Marquis Watershed which shows water intakes (Talvern, Marquis, La Sorciere 1 and La Sorciere 2) and their proximity to various land uses (Woolhouse et. al., 2019)[3].

4.2 Tourism and other sectors

The Saint Lucian economy has undergone structural adjustments since 1990 towards a service based sector revolving around tourism; this showed a decline in agricultural GDP from 13 percent in 1992 to 4 percent in 2012 and an increase for tourism, from 9 percent to 13 percent between 1990 and 2006 (FAO, 2015). Tourism is regarded as the centre of economic thrust among sectors such as agriculture, infrastructural development and commerce. Agriculture however, plays a central role in the local economy, serving for employment, food security and curbing urban drift (FAO, 2015).

As seen in Figure 3, hotels are the second highest consumer of potable water next to domestic users. From a GDP contribution standpoint, a green economy scoping study published in 2016 showed similarity between the construction sector and hotels and restaurants, with tourism spin-off sectors such as real estate renting and small business activities contributing the highest (see Figure 9) (UNEP, 2016). Peak tourism activity usually coincides with dry season months from December to May, hence creating spikes in water demand during very dry periods like that which occurred in 2010 and 2020 (CariCOF, 2020) resulting in droughts. These droughts warranted the official declaration of water related emergencies in Saint Lucia, for mandating water rationing schemes which also adversely affected the construction sector. Figure 2 exemplifies this by showing that the disparity between national water consumption and average national water demand peaked in 2010[4].

[3] Map was developed as part of an HR Wallingford sponsored study in collaboration with WASCO and the Water Resource Management Agency (WRMA).
[4] Figures from 2016 to 2020 for water production consumption and loss were not in the public domain during the period of the desk review for this perspective paper.

A 2016 study investigated the presence of point sources of pollution in 15 of the 37 watersheds in Saint Lucia (Government of Saint Lucia, 2016a). It was observed that the principal sources which pose risks to raw water are piggeries; poorly managed solid waste recycling facilities; disposal sites (for construction spoil, derelict vehicles and chemicals); agro-processing and chemical industries. The existence of quarries above and near sensitive water bodies such as water intakes in Anse La Raye to the west and Vieux Fort to the south have also been recognised (Montoute and Cashman, 2015; Government of Saint Lucia, 2016a). It is necessary to balance the economic impact of these enterprises with the implications for environmental services received from clean water and well managed land.

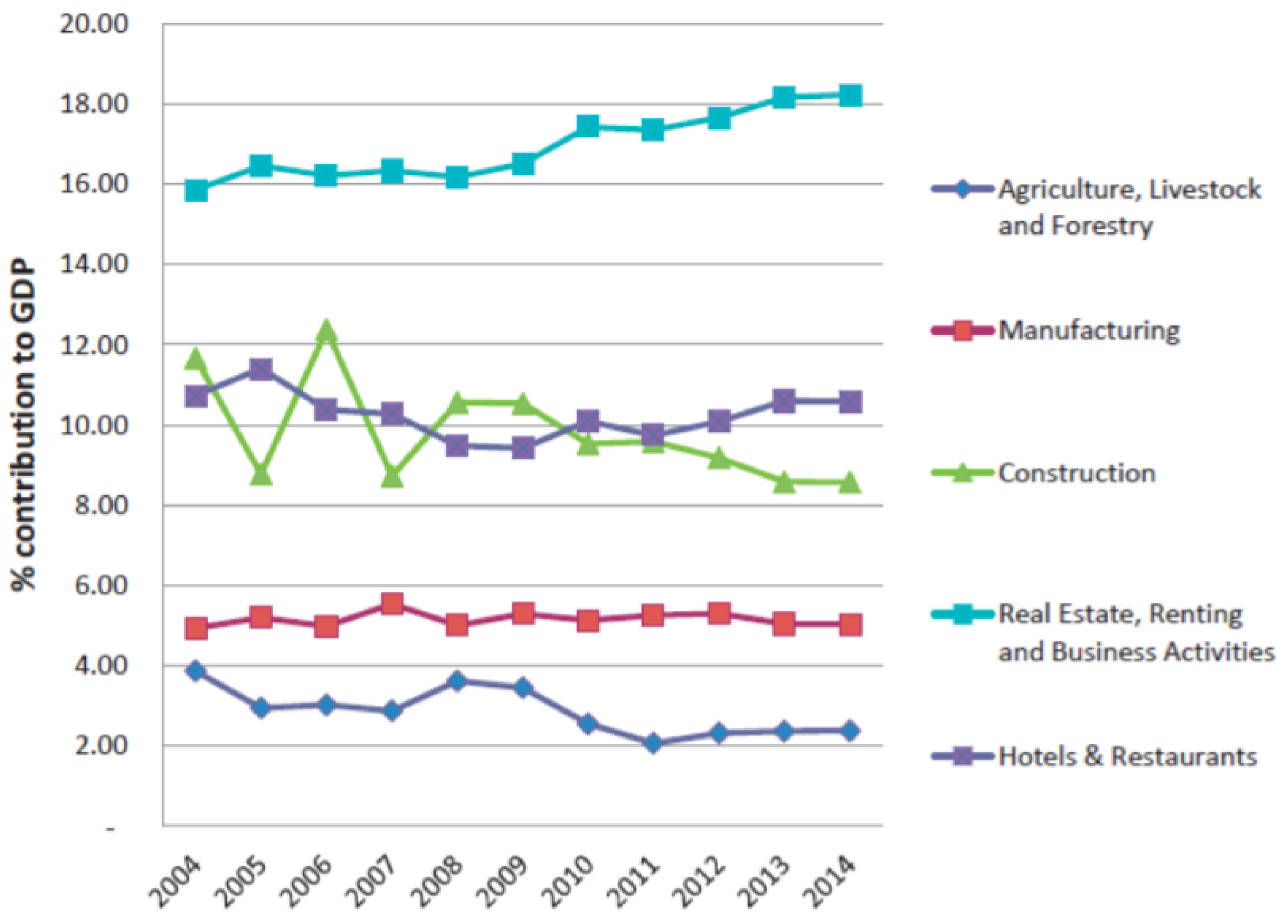


Figure 9: Trends in GDP contribution in Saint Lucia by sectors, from 2004 to 2014 (UNEP, 2016).

5. WASTEWATER MANAGEMENT

Water which has gone through any combination of domestic, industrial, commercial or agricultural use is called wastewater (Mugambi, 2020). Wastewater also includes surface run-off/stormwater, and any sewer inflow/infiltration (Mugambi, 2020). It can be characterised as blackwater when it contains excreta from sanitary applications and greywater when it comes from kitchens, laundries and bathing activities. Wastewater management is critical in dense urban areas which produce very high volumes of blackwater and greywater.

The City of Castries, considered the commercial centre and Rodney Bay (in Gros Islet), known as a hotel and tourism hotspot have sewer systems for collecting these high volumes. Proper wastewater management is vital in these coastal locations for safeguarding the surrounding marine spaces from high loads of point and nonpoint source pollutants.

Within the wider Castries Watershed, the high percentage of the built-up area forms a significant share of the non-permeable surface. This induces high flow velocities of rainfall runoff due to steep surrounding terrain (See Figure 10) and increased flood risk from surface runoff (Government of Saint Lucia, 2017a). The steepness of the landscape in combination with heavy rainfall as experienced during the tropical trough system on December 24 and 25, 2013 (rainfall exceeded 224 in 2 to 3 hours) were responsible for major flash floods and landslides in Castries and eleven other districts throughout the island (Government of Saint Lucia, 2014). Therefore, in addition to wastewater management, effective stormwater infrastructure and upper watershed bioengineering are necessary to curb the current flooding problems in Castries City and other low lying towns and communities during the rainy season.

A 2017 background paper for wastewater management in Saint Lucia reported that only 7 percent of all domestic blackwater produced in Saint Lucia is sewered, with the majority channelled into septic tanks (See Figure 11) (Government of Saint Lucia, 2017b). About 2 percent of the sewered component goes to the Beausejour wastewater treatment plant in Gros Islet, in the north of the island, and 5 percent to the Castries city sewer network. Therefore, only the 2 percent entering Beausejour wastewater treatment plant undergoes acceptable treatment before being disposed of into the marine environment.

Coastal villages such as Anse La Raye (Montoute and Cashman, 2015) and Canaries are also in need of wastewater management interventions because the proximity to the sea and high water table in these areas make septic tank and soak-away systems less effective and likely sources of coliform contamination during high tides, storm surges and flood events. Appropriate low cost, low maintenance systems should therefore be developed for these villages while larger scale wastewater treatment facilities are needed for the larger urban centres like Castries.

Greywater management has also been noted as an issue of concern with about 34 percent from 38 hotels and 76 percent from 122 industries being discharged directly into the environment without adequate treatment (Government of Saint Lucia, 2017b). The proper management of greywater should also be part of the wastewater management conversation as Figures 12 and 13 show that it accounts for the bulk of wastewater which is directly discharged into the environment from industries and hotels in Saint Lucia. The point can therefore be made that increased urbanisation accompanies great challenges related to wastewater management which are costly to remedy especially near marine and riverine environments with sensitive aquatic ecosystems.

It has been reported that a significant percentage of the Saint Lucian population in low-lying, coastal villages and poorer peri-urban and rural areas may not have the financial means to cover proper wastewater management costs; as these costs go beyond mere sanitation installations to include proper treatment which is site appropriate (Government of Saint Lucia, 2017b). The lack of land ownership also poses constraints to tenants who are willing to invest in the necessary infrastructure and associated fees.

It is important that all settlement planning makes provisions for future wastewater infrastructure and services as a means of protecting water resources and public/environmental health. This is difficult with rapid urbanization and illegal unplanned settlements, but proper wastewater disposal and treatment should not be disregarded.

Table 2 shows fourteen proposed[5] zoning clusters for Saint Lucia which can be used for prioritizing and determining appropriate wastewater management interventions/technologies (Government of Saint Lucia, 2017b). The clusters were based on the criteria such as water table height, settlement structure (formal or informal) and land tenure as outlined in Table 3 (Government of Saint Lucia, 2017b). It can be seen that Castries city falls within zone category 1 with a high health and environmental risk level. Some other areas which should be highly prioritized for wastewater management interventions are: coastal towns and villages; high density, informal settlements; and livestock farms. This emphasizes the importance of properly regulating land uses which generate significant amounts of wastewater due to their implications for recreational water safety and public health.

[5] Zones/Clusters for wastewater management were proposed by a joint venture of ECOPSIS and FDL Consult Inc. for the Government of Saint Lucia under a Disaster Vulnerability Risk Project (DVRP) initiative.

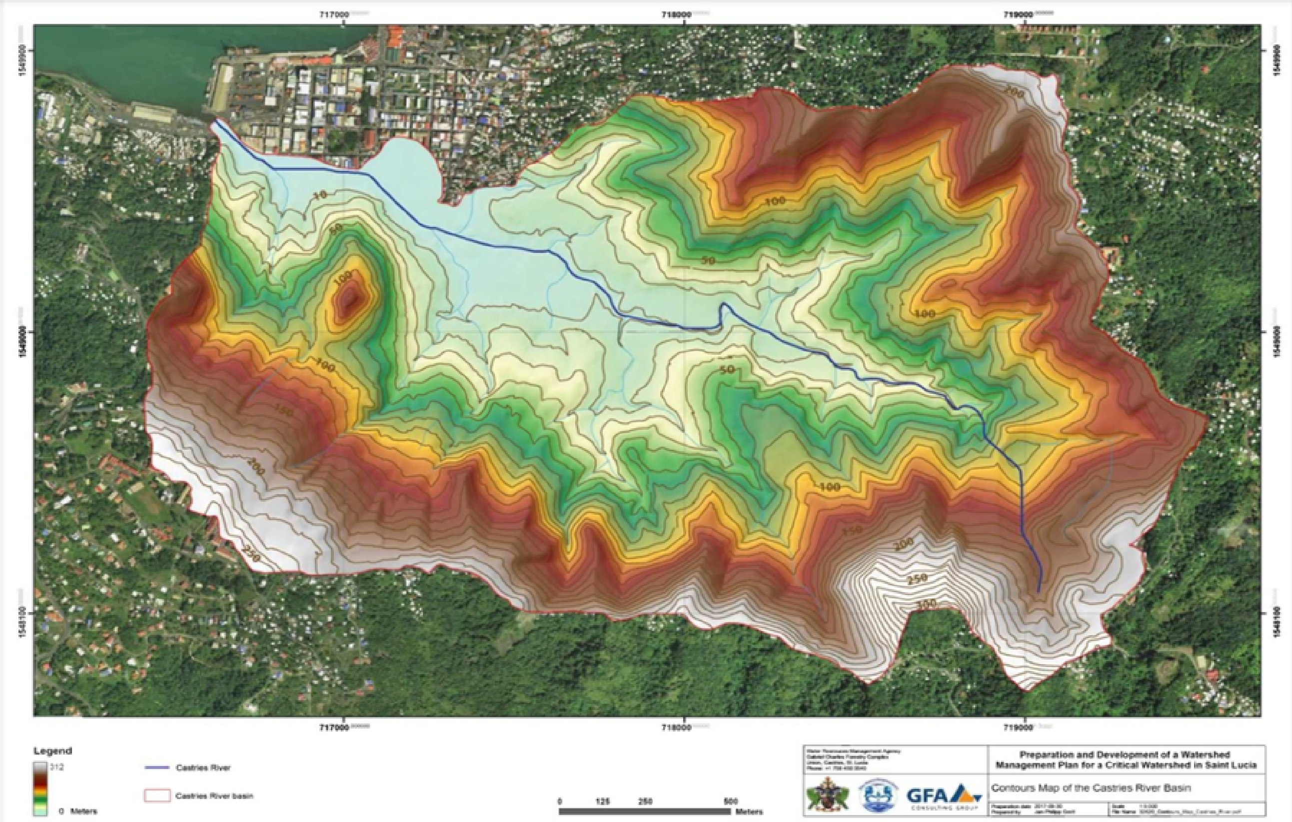


Figure 10: Contour map of the Castries River Basin (Government of Saint Lucia, 2017a)[6].

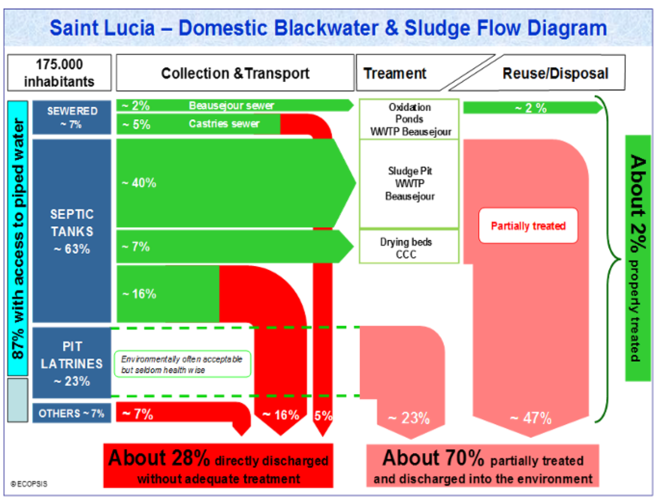
Zones / Clusters	Risk Level	Service Demand
1. Main Urban City Centre	High	Medium
2. Coastal Town and Village	High	High
3. High Density, Informal Settlement	High	High
4. Rural Village	Low	Low
5. Low Density – Low Standard	Low	Medium
6. Low Density – Medium/High Standard	Low	Low
7. Industrial activities	High	High
8. Hotel & Restaurant	Medium	Medium
9. Petrol Station & Car Wash Area	Medium	Medium
10. Livestock Farm	High	High
11. Non-Point Source pollution (NPS)	High	Medium
12. Marina & Harbor	Medium	Medium
13. Institutional Building	Low	Low
14. Hospital, Health Centre	High	High

Table 2: Possible wastewater management zones/clusters in Saint Lucia, in relation to risk level and service demand (Government of Saint Lucia, 2017c).

[6] Contour map was developed by GFA Consulting Inc. as part of a Watershed Management Plan for Castries developed for the Government of Saint Lucia, under the Disaster Vulnerability Risk Project (DVRP).

Physical parameters	Water and sanitation	Community development and capacity
❒ Geographic localization (mountain, coastal, rural) ❒ Topography (relief, slope, altitude etc.), ❒ Geology (soil type, landslide risk, infiltration capacity), ❒ Water table	❒ Water supply, ❒ Type of wastewater produced (organic material, solids, nutrients, toxic chemicals, heavy metals, grease, oil, etc.), ❒ Vicinity to sewer systems, ❒ Open defecation	❒ Settlement density (high, low), ❒ Settlement structure (formal, informal), ❒ Size land plots, ❒ Socio-economic conditions (financial capacities of inhabitants and communities) ❒ Situation land title

Table 3: Criteria and parameters used for possible zones/clusters for wastewater management interventions in Saint Lucia (Government of Saint Lucia, 2017c).



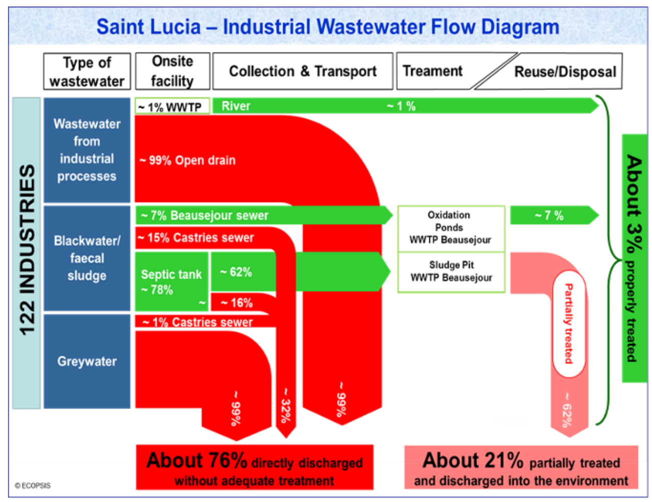


Figure 11: Domestic blackwater and sludge flow[7] diagram (Government of Saint Lucia, 2017b).

Figure 12: Industrial wastewater flow[8] diagram (Government of Saint Lucia, 2017b).

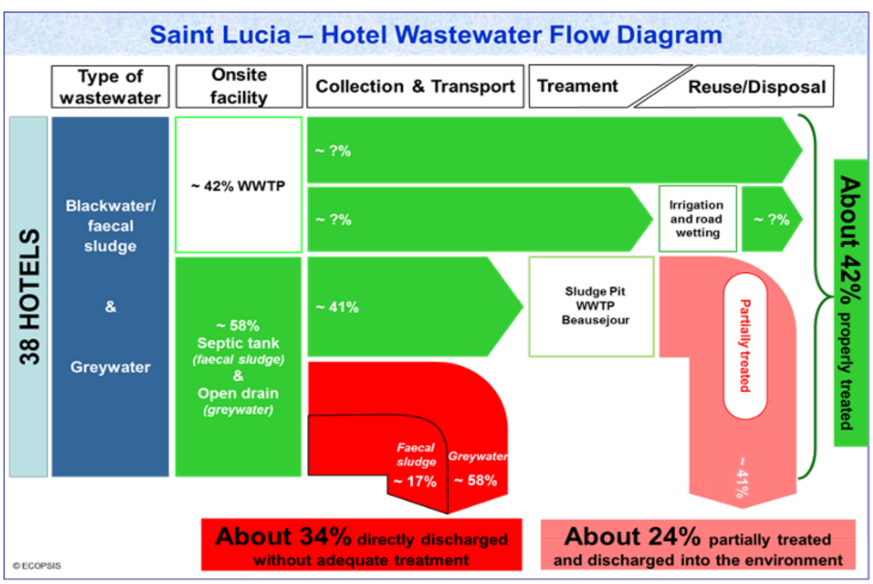


Figure 13: Hotel wastewater flow[9] diagram (Government of Saint Lucia, 2017b).

[7] Prepared by ECOPSIS for the National Policy on Wastewater Management (in Saint Lucia).
[8] Prepared by ECOPSIS for the National Policy on Wastewater Management (in Saint Lucia).
[9] Prepared by ECOPSIS for the National Policy on Wastewater Management (in Saint Lucia).

6. CLIMATE CHANGE, VARIABILITY AND DISASTER RISK IMPLICATIONS

The relationship between climate change and land use has been regarded as complex, and it has been shown that future land use patterns are shaped to a greater degree by urbanization as compared to the influence of climate change (Haim, 2011). However, land use practices which cause deforestation as a precursor of urbanization, lead to reduced carbon sequestration if destroyed forests are not reforested. Less carbon sequestration means that there is more atmospheric carbon available for global warming. Furthermore, forested lands and urban areas also have direct effects on rainfall patterns and temperature patterns (Haim, 2011). Forested lands promote rainfall and land clearances have an inhibitive effect on precipitation (Webb, 2005). Land changes can have climatic consequences related to precipitation and temperature, which eventually impact baseflows and streamflows. It can therefore be said that anthropogenic land degradation can exacerbate the impacts of climate change as it relates to the sustainability of water resources in Saint Lucia and the rest of the Caribbean region.

Climate change in turn can impact land use due to expected increases in the frequency and severity of forest fires, which lead to land degradation, desertification and soil erosion. This is further impacted by poor agricultural practices which deplete the moisture of soils hence creating less resilience during the dry season and increased soil erosion during the wet season. Low lying coastal cities, towns and villages will also be more vulnerable to sea level rise, hence impacting unsuitably adapted wastewater management and sanitation systems by increasing the risk of high effluent contamination of freshwater and marine environments. The technologies for mitigating wastewater management issues should therefore be climate proofed as part of developmental and climate change adaptation interventions.

In the long-term, climate change is expected to adversely impact SIDS such as Saint Lucia (Pelling and Uitto, 2001). Nurse et. al. (2014) have highlighted the average rainfall records for the Caribbean region spanning 100 years (1900 to 2000) and showed a consistent reduction in rainfall of 0.18 mm per year and there are expectations of this continued trend. This is expected to have a long-term reduction in the hydrology of small islands and the streamflow of rivers, hence impacting territories like Saint Lucia which mainly depend on surface water.

There is also an expected influence on seasonal climate variability phenomena, namely, the El Niño Southern Oscillation (ENSO) phenomenon (El Niño and La Niña) (Bertrand et. al., 2020). The ENSO events typically occur every 3 to 7 years (Tompkins et al., 2005) with El Niño being more frequent than La Niña. In the Caribbean, El Niño events are generally accompanied by drier conditions, and wetter conditions are associated with La Niña events (see Figures 14 and 15) (Bertrand et. al., 2020); hence leading to conditions of extreme drought as well as more frequent intense rainfall respectively. Taylor et. al. (2012) noted that El Niño enhances hurricane activity whereas La Niña suppresses it. It is therefore likely that climate change and variability will increase the frequency and severity of droughts and floods which have dire implications for islands which are water stressed.

Saint Lucia has experienced floods and droughts which may be associated with ENSO phenomena. Floods have been the result of excessively high rainfall events which sometimes accompany land slippage along the various steep slopes within the island's hilly interior, hence further exacerbating the issues of high river sediment loads during the wet season. This leads to increased water intake blockage and damage, leading to prolonged periods of potable water supply stoppage while these intakes are being desilted. This creates a relatively high frequency of potable water supply intermittency during the wet season. Reservoirs and dams will also be significantly reduced in capacity from a higher rate of sediment accumulation hence warranting extensive unplanned de-silting programmes, as is the case with the John Compton Dam in Saint Lucia which was significantly affected after the passage of Hurricane Tomas in 2010.

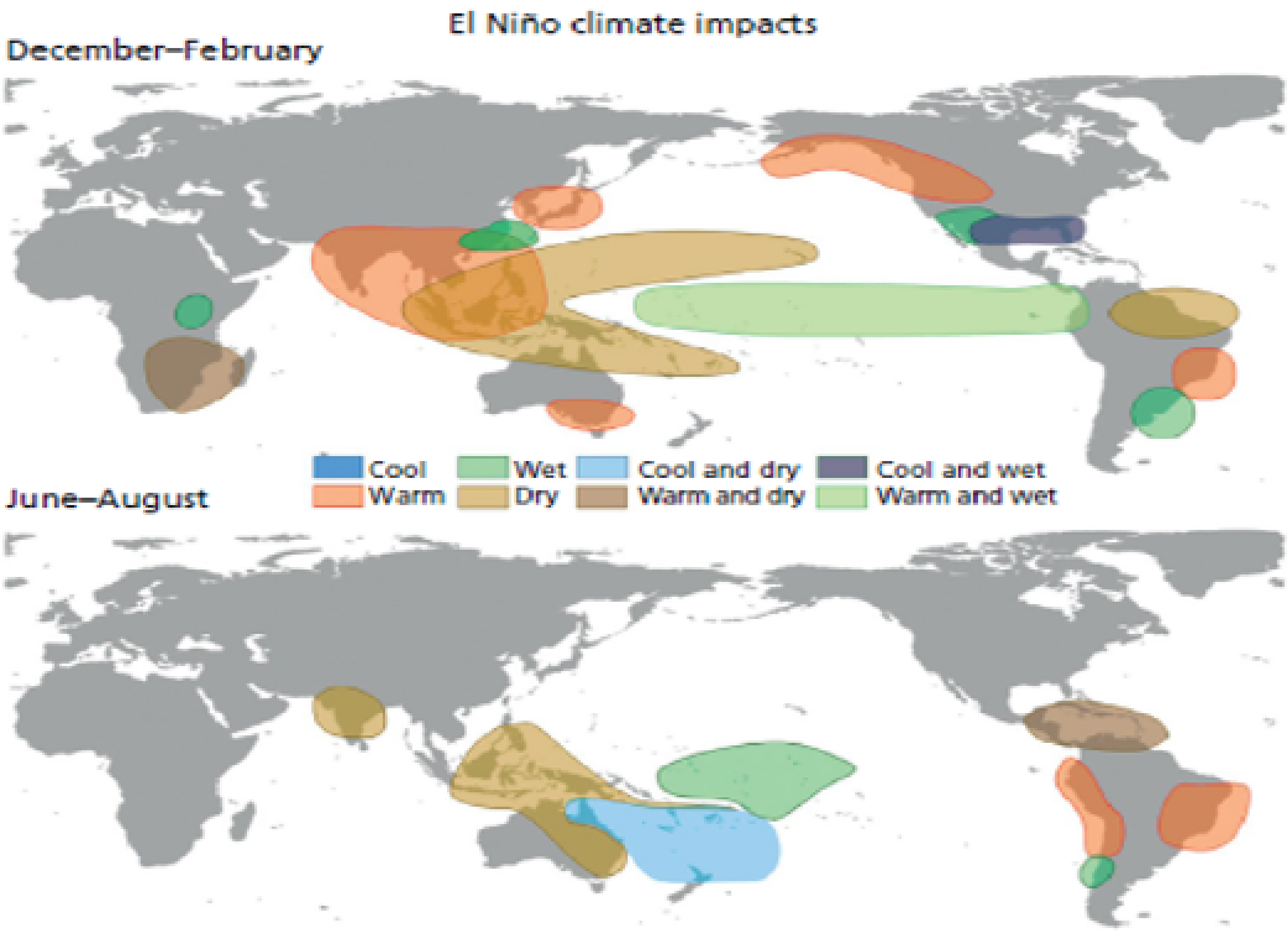


Figure 14: Climate impacts of El Niño: NOAA image modified by Bertrand et. al. (2020).

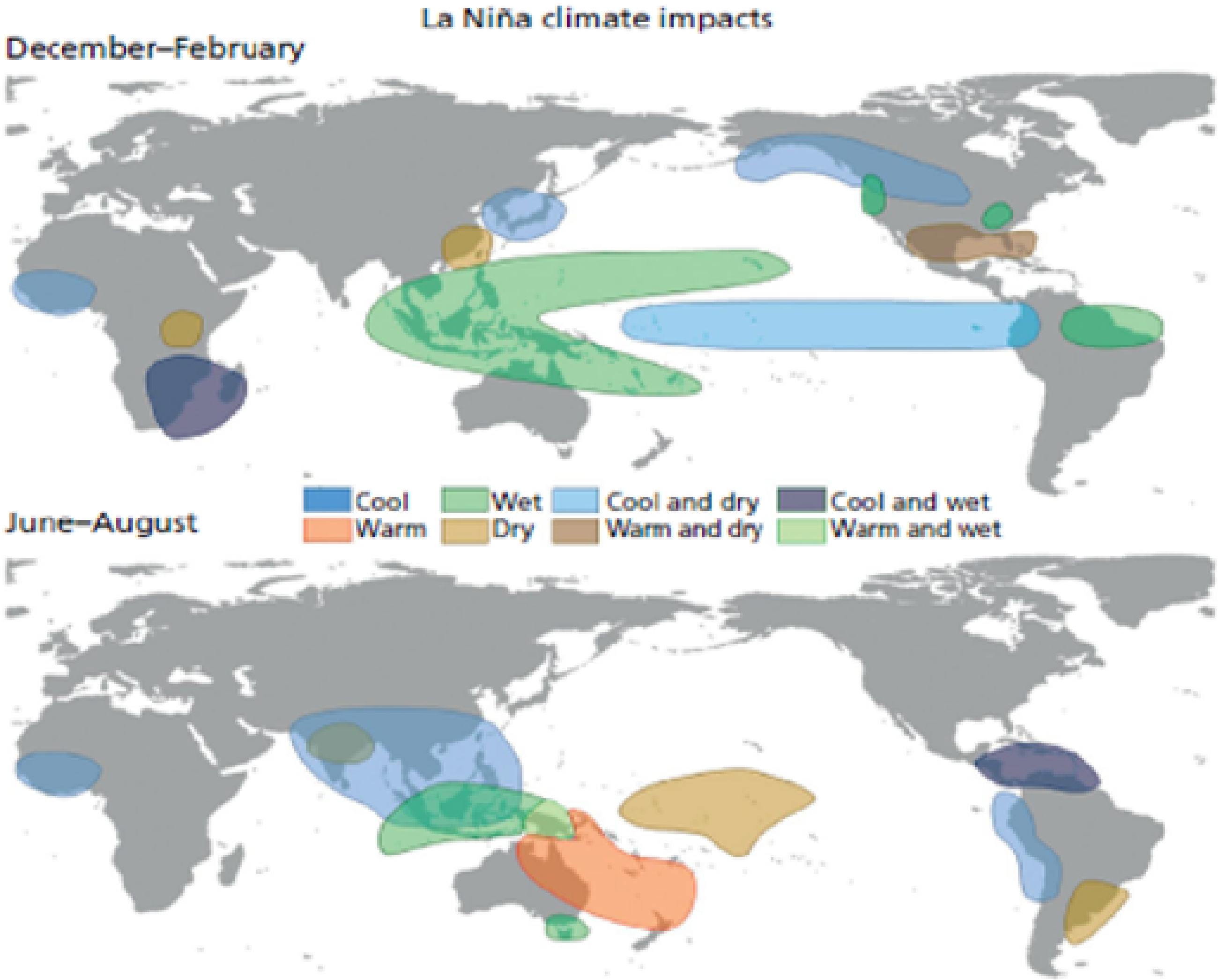


Figure 15: Climate impacts of La Niña: NOAA image modified by Bertrand et. al. (2020).

Notable drought conditions which coincide with El Niño in the Caribbean occurred during the following years: 1957, 1968, 1976-77, 1986-1987, 1991, 1994, 1997-1998, and 2009-2010 (FAO, 2016). Since the wet season tends to offset droughts, extended drought conditions create delays in the replenishment of the John Compton Dam which supplies water to the country's major urban, economic and tourism centres.

Woolhouse et. al. (2019) looked at long-term water supply-demand balance challenges in the Marquis Watershed using a Probabilistic Distributed Model (PDM) from a 60 year time series of daily rainfall and potential evaporation data (PET). The model estimated that climate change may reduce flow rates in this watershed by about 40 percent for the 2050s and to a higher degree of 50 percent to 70 percent for the 2080s, as compared to the baseline period of 1970 to 2000. The estimates show that the average of 15 days of water shortages experienced could be extended to 50 days by the 2050s and 100 days by the 2080s; they inferred that introducing a reservoir, reducing leakages and effective demand side management should have notable benefits by augmenting supply during periods of droughts.

With increased raw water demand from farmers in mixed farming areas near the Talvan and Marquis intakes (See Figure 8), high water abstractions from rivers are expected during droughts, which will be prolonged due to climate change. Also, the erosion occurring from unsustainable forms of soil tillage and farm land preparation will lead to further increases in water intermittency during the wet season especially with expected increases in the frequency of tropical storm activity and higher rainfall intensity. Appropriate zoning and state land acquisition interventions with effective enforcement are required around these intakes to regulate land use. These should be applied in conjunction with appropriate economic incentives such as payment for environmental service schemes which have been proven to be more effective in agricultural watersheds (Langpap et. al., 2008).

7. POLICY DEVELOPMENT, PLANNING AND IMPLEMENTATION

The Revised National Land Policy of 2016 and the Water Policy of 2004 (under revision in 2020) recognise the importance of the water-land management nexus. This is specified in the National Land Policy of 2016 in its third strategic imperative: "The protection of all water intakes, rivers and important watersheds" (Government of Saint Lucia, 2016b, pp.5). This protection can be made possible through developing and implementing a national land use plan with enforceable regulations for zoning based on land use activities which affect sensitive environmental resources. Currently, the lack of robust physical planning legislation currently precludes the development of an effective national land use plan in Saint Lucia, although it is mentioned in the Physical Planning and Development Act (Government of Saint Lucia, 2016b).

An on-going 2020 review of The Saint Lucia National Water Policy of 2004 (by the World Bank) in keeping with Integrated Water Resources Management (IWRM) principles highlighted weak land management practices as a significant factor which undermines the sustainability of water resources management (Government of Saint Lucia, 2020). This has been linked to the island's colonial legacy of an inefficient and antiquated deeds registration system which makes land transfer difficult, costly and risky hence leading to numerous cases of land fragmentation or situations of family land tenure. This creates difficulty when conducting land transactions due to the challenge of contacting and identifying descendants/owners. It was also noted that the nexus between land and water is limited by the 1978 constitution which protects individual rights over property but makes no mention of collective rights in relation to a healthy natural environment. This has therefore led to the use of second level legislation with various fragmented laws and regulations as a means of managing natural resources (Government of Saint Lucia, 2020).

Effective water and land management start from sound policy and legislation development/review for creating an enabling environment from which the mandated institutions can effectively execute their roles through the necessary management instruments. However, the lack of a suitable land use plan with zoning regulations in Saint Lucia is a significant barrier to proper IWRM implementation as land use impacts the quality and quantity of environmental flows for the sustainable benefit of competing users.

We need to develop ways of strengthening the enforcement of environmental regulations geared at effectively managing land and water resources. These enforcement mechanisms should be applied in tandem with instruments for public sensitization and awareness; restriction of access; land acquisition and swapping; moral persuasion; and market based and economic incentives such as payment for environmental services.

8. CONCLUSION

From the Saint Lucia perspective it can be seen that land and water management are complex interlinked issues which should not be managed in isolation, as deficient land policies and poorly enforced regulations perpetuate unrestrained encroachment into pristine water catchments. A land use and zoning plan needs to be developed. Land use enforcement for source water protection should be guided by regulations which foster effective regulatory instruments based on categorized developmental zones in relation to the risk and costs of their environmental impacts. The nexus between land and water management should also be less fragmented for a better integration of land and water management plans and supporting regulations. This will also require greater coordination among agencies with a mandate for protecting land and water resources.

The land tenure system should be regularised to ease the private registration of lands for implementing mechanisms for direct land acquisition by the state, in sensitive catchment areas under threat from unsustainable land use activities. This will be necessary for ensuring that these lands maintain forest cover through reforestation and afforestation schemes. The regularization of land tenure systems will also incentivize private landowners, who should make the financial investments necessary to improve land use for decreasing degradation, reducing water pollution and restricting squatting.

Climate change can exacerbate poor land use through higher frequency of forest fires which further degrades deforested lands and farmed soils; hence increasing soil erosion and augmenting silt loads within rivers. Forest cover is important to water availability since it promotes rainfall and subsequent baseflows and streamflows. Climate change will also worsen the adverse effects of land use change by lowering these flows from springs, rivers and streams during the dry season. Saint Lucia has recognized the need for identifying and prioritizing climate change adaptation measures in the water sector through the development of a National Adaptation Plan (NAP) and the SASAP. The broad stakeholder consultation process for developing the NAP recognised the water sector as the top priority for implementing climate change adaptation measures and interventions, however mobilizing climate finance for the implementation of the proposed SASAP initiatives have been challenging.

Water supply-demand relationships should also be used as a tool to project demand over time due to increased urbanization, population changes and seasonal demand spikes during the tourist season and dry season. The projected influence of climate change on this demand will allow water managers to plan ahead through a combination of water augmentation and demand side management measures.
The promotion of sustainable land use interventions such as bench terracing, intercropping, bioengineering and check dams are necessary for curbing the effects of soil erosion along steep slopes, which lead to water intake clogging and reservoir/dam volume deficiencies; this will help with water intermittency issues during the wet season.

Finally, good wastewater management is vital for protecting water sources from effluents from homes, farms, industries and commercial activities. Zoning clusters should guide the implementation of appropriate, zone specific interventions, which vary based on physical parameters (landscape, geography and geology); water and sanitation; and community development/capacity criteria. These prescribed clusters/zones should feed into any future land use and zoning plan as a means of enhancing synergies among national land, water and wastewater management initiatives. Land use clusters which are seen as having high priority due to the risk of environmental and water quality impairment include the main city centre, coastal town and villages, high density informal settlements and livestock farms. The interventions and technological solutions applied to these areas should take into consideration the upfront cost of the technologies and their proper maintenance. The impact of inadequate wastewater management on recreational water quality and aquatic ecosystem health is a cause of concern, which requires immediate attention, through the use of effective management instruments and appropriate technologies in elevated catchment areas and coastal towns and villages.

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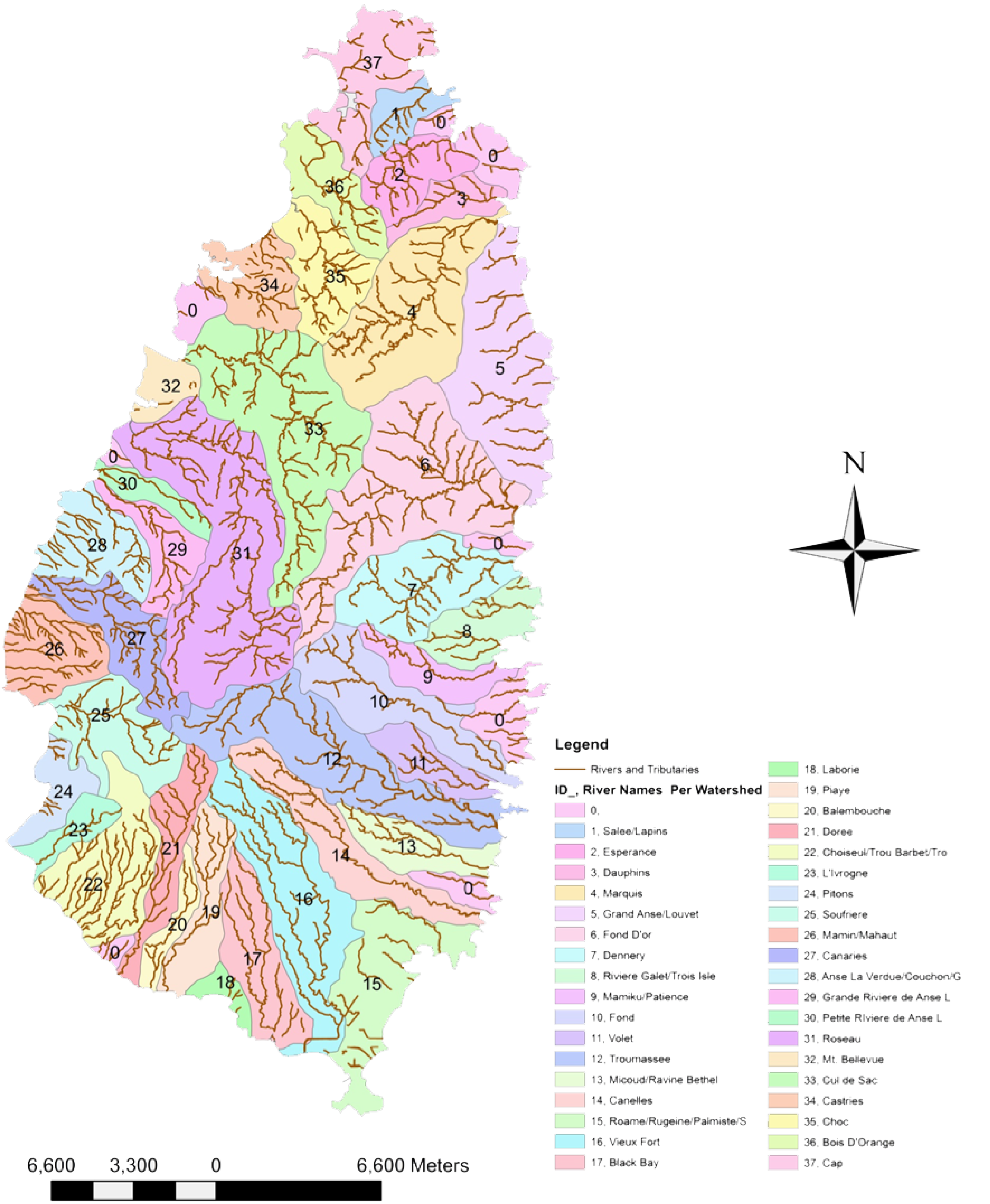
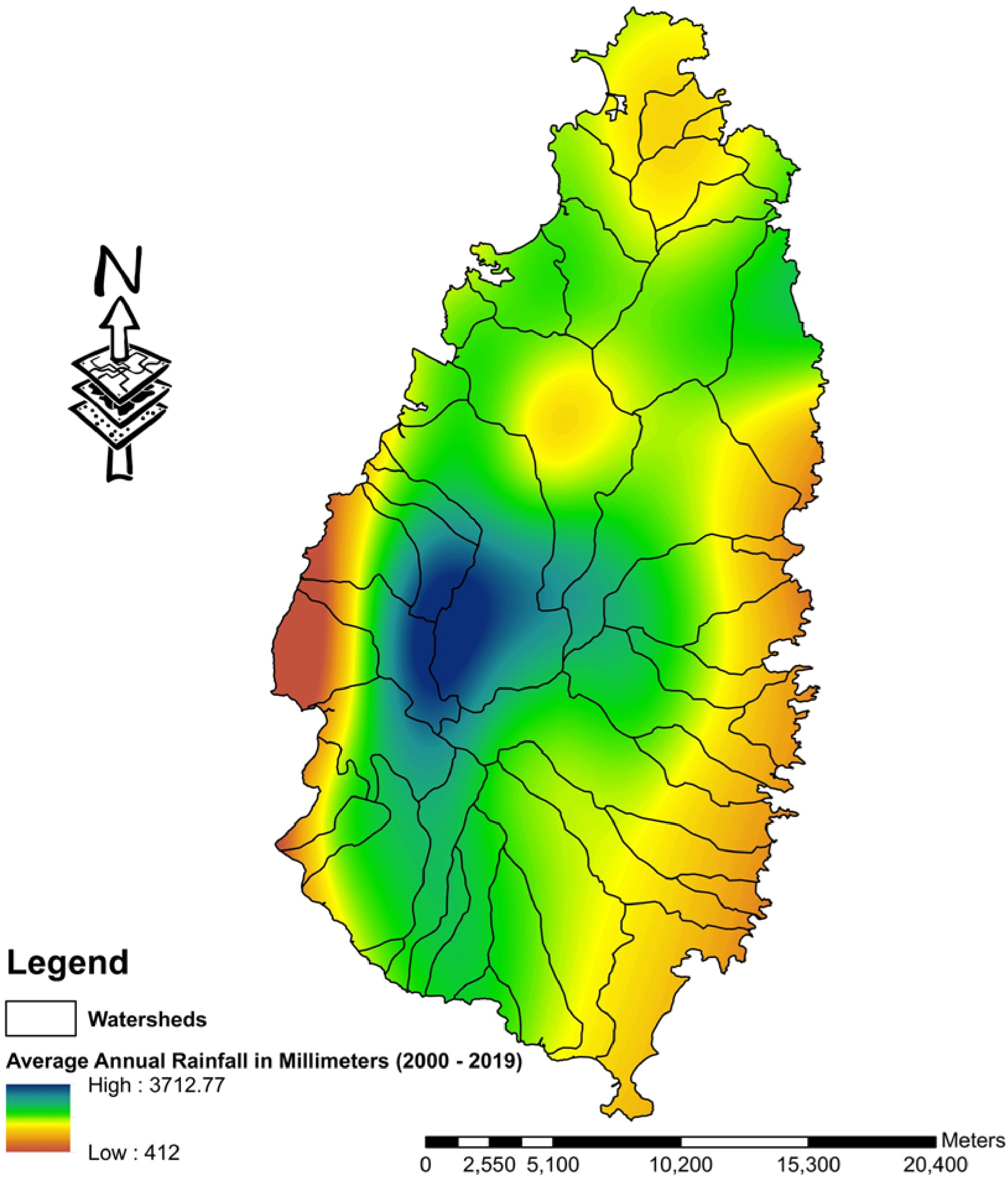
MAP SHOWING WATERSHEDS AND RIVERS IN SAINT LUCIA



Prepared by: Water Resource Management Agency (WRMA) - Saint Lucia, 2020.

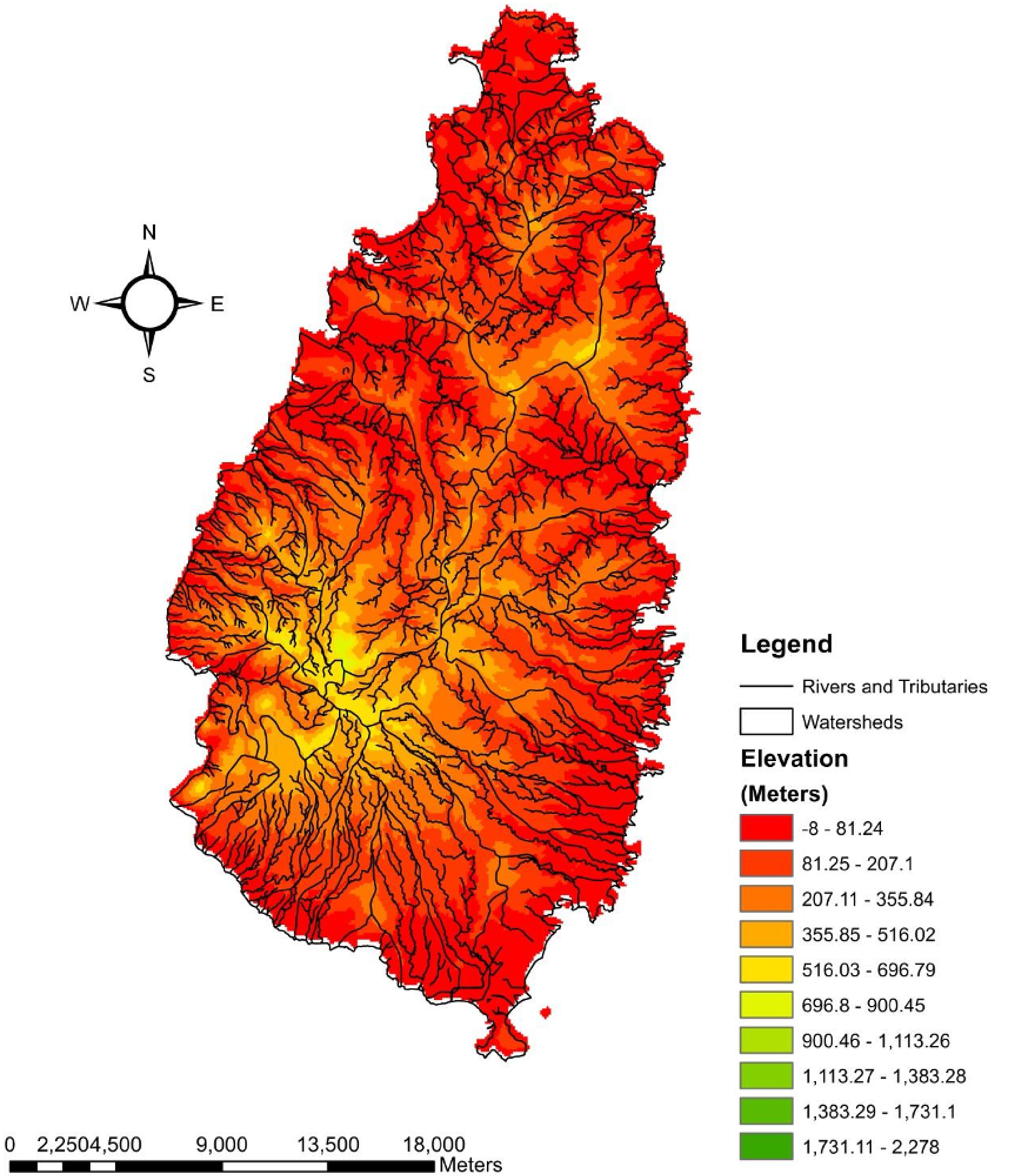
AVERAGE ANNUAL RAINFALL DISTRIBUTION MAP OF SAINT LUCIA



Prepared by: Water Resource Management Agency (WRMA) - Saint Lucia, 2020.

[10] Provides a rough average annual rainfall estimate as yearly and monthly gaps existed in the 2000-2019 dataset

TOPOGRAPHIC MAP OF SAINT LUCIA SHOWING WATERSHEDS AND RIVERS NETWORK



Prepared by: Water Resource Management Agency (WRMA) - Saint Lucia, 2020.

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