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Environmental Assessment by Vulnerability Analysis of Water Intended for Human Consumption in Urban Environments: A Case Study of the N'djili River, Kinshasa

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Abstract

Background: The Water Distribution Administration of the Democratic Republic of Congo (REGIDESO) faces many challenges, particularly related to unregulated human activities on all watercourses used for the treatment of water intended for human consumption in general and in particular around the watershed of the N'djili River, a river that feeds the largest water treatment plant in the Democratic Republic of Congo (DRC). **Aim:** This contribution is based on the assessment of the vulnerability of the N'djili River to human activities around it in order to propose recommendations for a water safety health plan. Methods: An environmental study was conducted to identify the sources of pollution and their proximity to surface and groundwater. An analysis of water vulnerability was then carried out, followed by monitoring of this area using geographic information system and remote sensing tools. **Results:** During the environmental survey, we identified several sources of water contamination, mainly chemicals used in agricultural areas to increase the profitability of market gardening, domestic wastewater, industrial wastewater and fecal matter. The calculation of the water protection perimeters of the N'djili River and the boreholes observed in the study area shows a non-compliance with these perimeters. It was found that the immediate protection perimeter is occupied by activities likely to pollute the water; This is the case of the close protection perimeter where domestic and industrial activities; Agricultural activities; Commercial activities and road transport are the major sources of contamination. Water quality monitoring by NDWI and NDCI shows an average rate of dissolved solids in a high humidity area. **Conclusion:** To combat these problems, the DRC government, through the Ministries of Water Resources, Public Health, Environment and Urban Planning, must put in place a solid water safety plan, which will combat several consequences that these problems have for the health of the population.

Subject Areas

Environmental Engineering

Keywords

Contamination, Protection Perimeters, Water Security Plan, WIHC, NPK

1. Introduction

Water is of paramount importance, biologically and economically. The hydrosphere is the foundation of life and ecological balance. Water is both a food, possibly a medicine, an industrial, energy, and agricultural raw material, and a means of transport. The degree of water quality required obviously depends on its uses, and particular attention is paid to the quality of water intended for human consumption (WIHC), itself dependent on available water resources [1]-[3].

The hydrosphere is obviously in contact with the other spheres: The lithosphere, biosphere, and atmosphere. Exchanges exist between these different sectors, depending on the nature of the contaminants. Various sources of pollution affect water resources, including thermal pollution, radioactive pollution, mechanical pollution, biological pollution (microbial and parasitic), and chemical pollution [4].

Water intended for human consumption (WIHC) must meet water potability standards. It must be physically, chemically, and microbiologically treated according to the standards of the World Health Organization and the European Union. Drinking water intakes, the first link in the drinking water supply chain, are particularly subject to pressures induced by global changes (climate change and urbanization), facing quantitative threats (availability of water surface) and qualitative threats (chemical and microbiological contamination) [5].

Several studies carried out in the watershed of the N'djili River as a whole show that this river is mechanically polluted, especially during the rainy season, chemically by sulphate and contaminated by other metallic trace elements (MTE) such as cadmium, arsenic, and zinc, but also microbiologically polluted [6] [7]. Groundwater has abnormal concentrations of nitrates from agricultural areas, which can seriously harm the health of consumers [2]. This pollution is the basis of several water-related diseases, such as malaria, which caused the deaths of 619,000 people in Africa in 2021 [8]; Cholera, which affected 80,000 people with 1863 deaths in 15 Africans in 2022 [9]; Typhoid fever; diarrhea; dysentery; and poliomyelitis. Contamination of water intended for human consumption causes an estimated 505,000 deaths each year from diarrheal diseases [10].

Water vulnerability must be taken into account because of the significant connection between health and water. Water vulnerability is hard to measure because it depends on biophysical and social factors that act at different scales [11]. Several methods are used to assess the vulnerability of water intended for human consumption. DRASTIC [12] is a numerical rating system that takes into account seven hydrogeological factors to determine a vulnerability index. AQUIPRO [13] is also based on a numerical rating but takes into account stratigraphic information only to estimate a vulnerability index. The approach developed by ROSS (2004) assesses vulnerability based both on stratigraphy, according to a three-dimensional view of the subsoil, and on vertical convective transfer time [14]. Finally, EVARISK [15] simulates the migration of a contaminant of diffuse origin in the water leached beyond the root zone and can be used to estimate the contribution of the contaminant to the water table. What these approaches have in common is that they do not take regional groundwater flow into account in their assessment of aquifer vulnerability [16].

Human activities are often the cause of the degradation of drinking water sources. For several years, some municipalities have experienced groundwater quality problems following contamination by polluting agents such as chlorides, aldicarb, hydrocarbons, and nitrates. Managing potential sources of contamination contained within the protection perimeters determined around catchment structures constitutes an effective method of preserving water quality [17].

The immediate protection perimeter is intended to protect the catchment works; it must be fenced and is generally grassed. No activity other than mechanical maintenance and upkeep of the structure is authorized. The close protection perimeter is defined to protect the catchment from the migration of polluting substances. It makes it possible to preserve the capture of the risks of accidental or occasional pollution. Activities or developments that could harm water quality are regulated or prohibited. The remote protection perimeter constitutes a particular vigilance zone, particularly with regard to accidental pollution, which could have consequences for the resource. Activities or developments within this perimeter are often regulated [18]. It is in this context that we conducted a study to assess the vulnerability of the waters around the water distribution administration of the Democratic Republic of Congo (REGIDESO) catchment on the N'djili River in order to see the exposure of water to sources of pollution with the objective of alerting the population and officials to the present danger. Finally, we have formulated recommendations to be taken into consideration for the development of a health safety plan for water intended for human consumption but also for the protection of ecosystems.

2. Methodology

For this study, we reviewed the literature before tackling the field approach. It was subsequently that we mapped the area remotely using geographic information system (GIS) tools to get an idea of the area. To do this, we downloaded digital terrain models from the Earth Explorer and Sentinel-2 websites, which we processed using ArcGIS, Global Mapper, and Surfer software to establish the maps necessary for this step. We moved on to the field phase, where we visited the municipalities of Matete, N'djili, Limete, and Masina to identify the sources of contamination of the water of the N'djili River and groundwater. The tools used for this step are a global positioning system (GPS) and maps for location, a digital camera, and smartphones for capturing field images. After the field phase, we moved on to processing the information received from the field. For the protection perimeters, we used ArcGIS and Surfer software.

We selected the region surrounding the N'djili watershed because it is home to the largest water treatment facility in the Democratic Republic of the Congo that is meant for human use. There are interactions between groundwater, raw river water, and treated water in the study area [2]. The N'djili catchment site is located in the municipality of Limete, downstream of the N'djili bridge crossing the N'djili River through Boulevard Lumumba. It is located to the south at 04˚23'12.6"; to the east at 15˚21'59.1"; And at an altitude of 284 m. The study area shown in Figure 1 is located around the REGIDESO N'djili catchment site. It takes a radius of 800 m from the collection point and touches the municipalities of N'djili, Matete, Masina, and Limete.

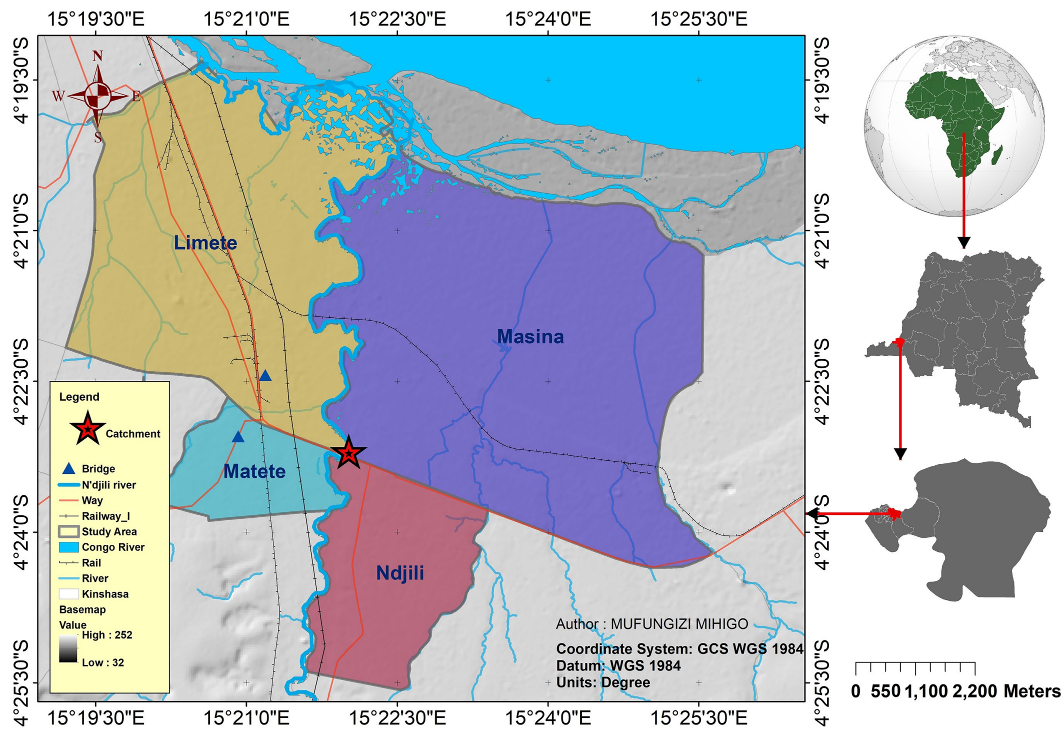


Figure 1. Location of the study area.

The topography of the area located 800 m around the REGIDESO N'djili catchment has a minimum value of 273 m, a maximum value of 299 m, an average of 281.15 m, and a median of 278.62 m.

Figure 2 presents the topographic map in 3D. The black arrows symbolize surface water flows. The falling water is collected at the divides; it flows while picking up the contaminants, which it discharges into the river (Figure 2(a)), and the lithologic model, including the study area, is shown in Figure 2(b). The study area is geologically characterized from top to bottom by the sands of Lemba, Silt, Kaolin Sand, Grained Sand, Polymorphic Sandstone, Soft Sandstone, Marly Sandstone and Sandstone of Inkisi [19]-[21].

McFeeters created the Normalized Difference Water Index (NDWI), which is a remote sensing instrument for monitoring the presence and variation of water surfaces. The NDWI uses satellite imagery to improve water body recognition by reducing interference from terrestrial elements like vegetation and dry soils. This review delves into the notion of the NDWI, its computation, applications, and limits [22]-[24]. The NDWI is calculated from reflectances in the near-infrared (NIR) and visible green (VIS) bands. The calculation formula is:

$$\text{NDWI} = \frac{\text{Green} - \text{NIR}}{\text{Green} + \text{NIR}} \tag{1}$$

where: Green is the reflectance in the green band (approximately 0.52 - 0.60 μm) and NIR is the reflectance in the near-infrared band (approximately 0.74 - 1.10 μm).

The NDWI uses the difference in reflectance between these two bands to emphasize water surfaces while reducing the high reflectivity of other surfaces, such as vegetation or dry soil [25]. We used Earth Explorer to get Landsat8 images from 2024 for our investigation. A is band 3, and B is band 5 in Figure 3, which shows the bands that were employed.

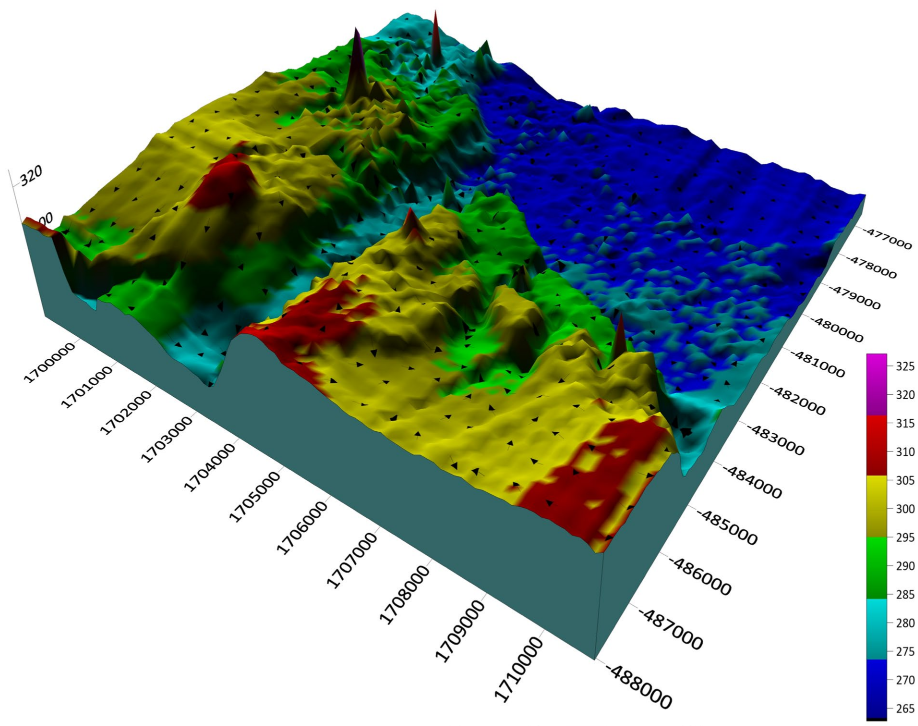
The goal of the NDCI index is to forecast the amount of chlorophyll in turbid productive waterways. The red edge spectral band B05 and the red spectral band B04 are used in the calculation [26]. To do this, we used Sentinel-2 satellite images with processing on ArcGIS according to the following formula:

$$\text{NDCI} = \frac{\text{B5} - \text{B4}}{\text{B5} + \text{B4}} \tag{2}$$

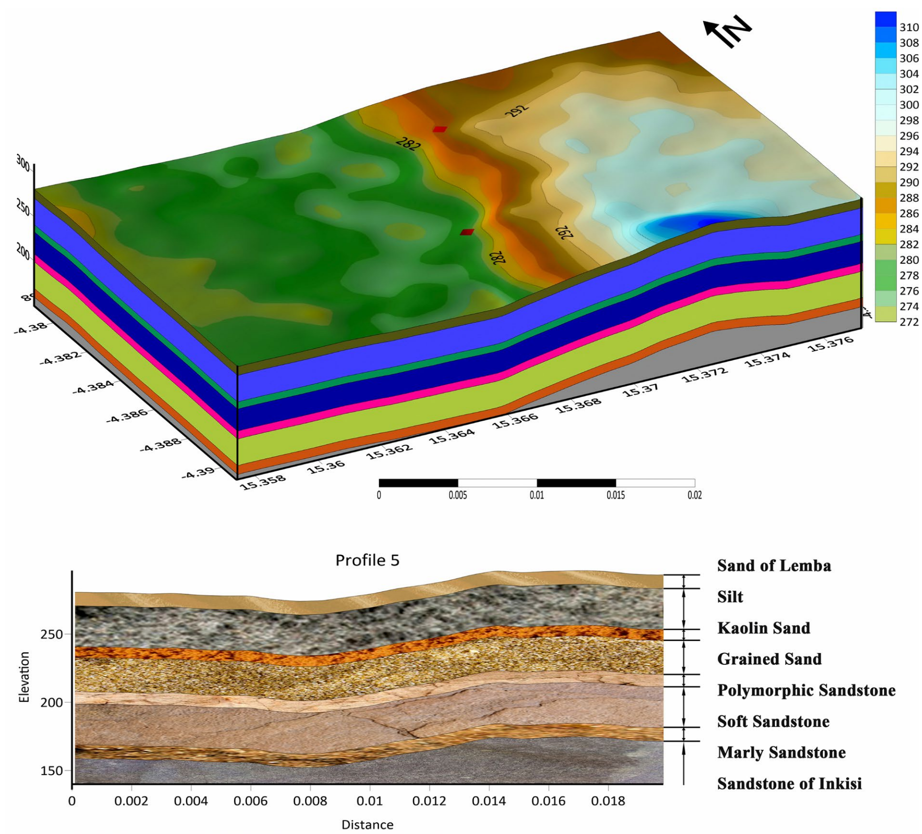
3. Results and Discussions

3.1. Hydro-Climatic Context

An essential component of the city's drinking water supply is the N'djili River. The public corporation REGIDESO (Régie de Distribution d'Eau de la République Démocratique du Congo), which is in charge of water distribution in the nation's capital, oversees the river's exploitation for human use. The retention basin established downstream of the N'djili bridge collects the water and keeps it at a consistent level for pumping all year round (Figure 4 and Figure 5). Before being transferred to the treatment facility, this water goes through physical treatment to remove big solid particles.



(a)



(b)

Figure 2. 3D topographic maps of the study area (a), 3D and 2D lithologic models of the study area (b).

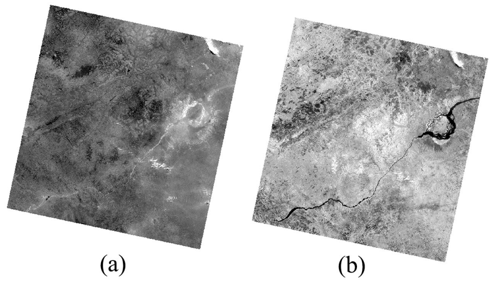


Figure 3. Input raster images: band 3 (a) and band 5 (b).

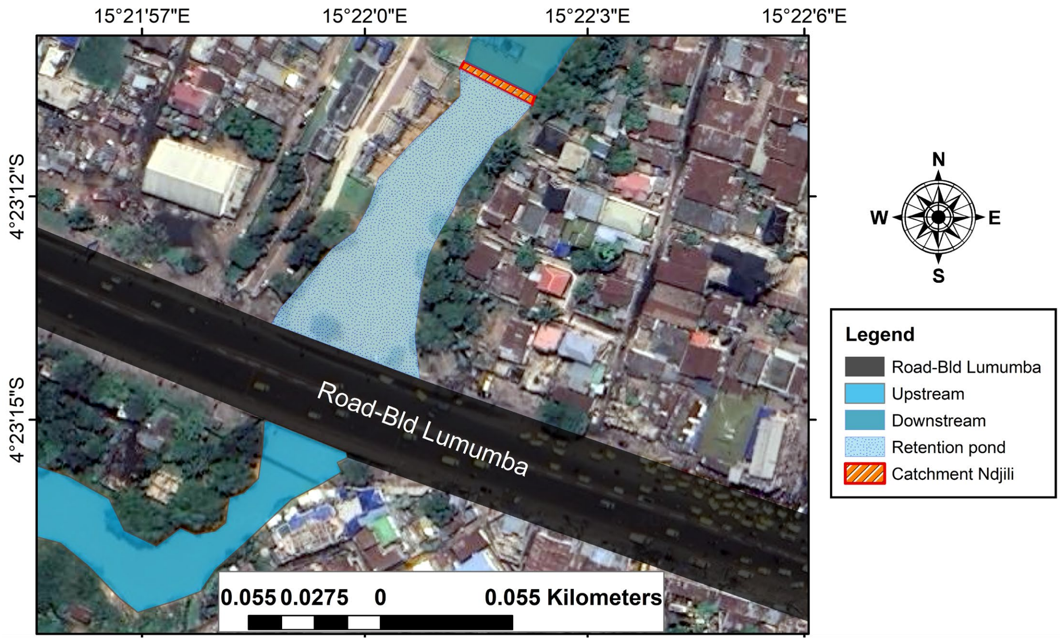


Figure 4. Map of the portion of the N'djili River affected by water catchment.

The first step in the process is capture: Using pumping stations, REGIDESO draws water from the N'djili River. The water is directed via these facilities to treat plants, where it is treated to make it safe for human consumption. To get rid of toxins and impurities, this involves filtration, disinfection, and purifying processes; distribution comes last. Following purification, the water is delivered to Kinshasa's residences, establishments, and companies via a system of pipelines and reservoirs. Rainfall determines the availability of water resources, highlighting the need to take climate setting into consideration. Kinshasa's climate is heavily influenced by its geographical position, with tropical conditions characteristic of equatorial countries. This review discusses Kinshasa's primary climatic features, such as temperature, precipitation, and seasons. Kinshasa's climate is typically warm throughout the year, with average temperatures ranging from 24 to 30 degrees Celsius. Minimum temperatures are usually about 23˚C, while maximum temperatures can reach 31˚C. This consistent warmth is caused by the city's closeness to the equator, which results in less diurnal fluctuations than seasonal differences [27] [28].

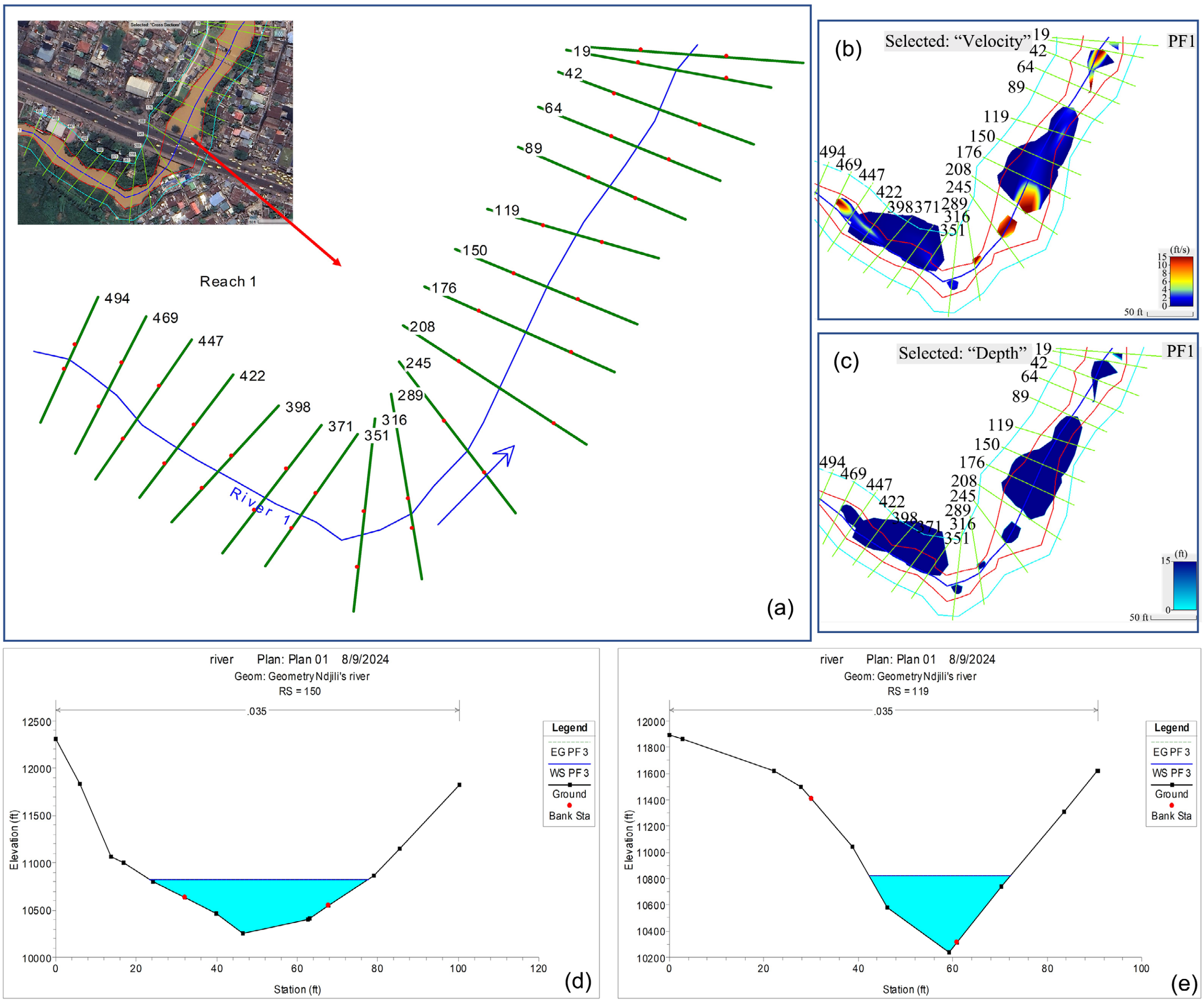


Figure 5. Presentation of the cross sections around the N'djili River in the upstream and downstream parts of the water catchment point (a); Flow velocity of the river (b); Depth along the river (c); Main cross sections of the retention basin ((d) and (e)).

Kinshasa has a typical tropical rainfall regime with considerable seasonality of precipitation. The average annual precipitation is around 1600 mm. The city has two primary rainy seasons: the first from March to May, and the second from September to November.

These seasons are separated by dry periods, which typically last from June to August and December to February, while rare rains may occur during these dry months [29]. Kinshasa's relative humidity is consistently high throughout the year, frequently exceeding 80%, adding to the sensation of extreme heat. Winds are often light, with average speeds of 2 to 4 m/s, limiting the natural cooling effect and exaggerating the impression of heat [30]. The precipitation data in mm/day from 1981 to 2022 are presented in **Figure 6(a)** where it is noted that the months of June, July and August have the lowest precipitation values and constitute the dry season. This is the case for **Figure 6(b)** which presents the relative humidity data from 1981 to 2022.

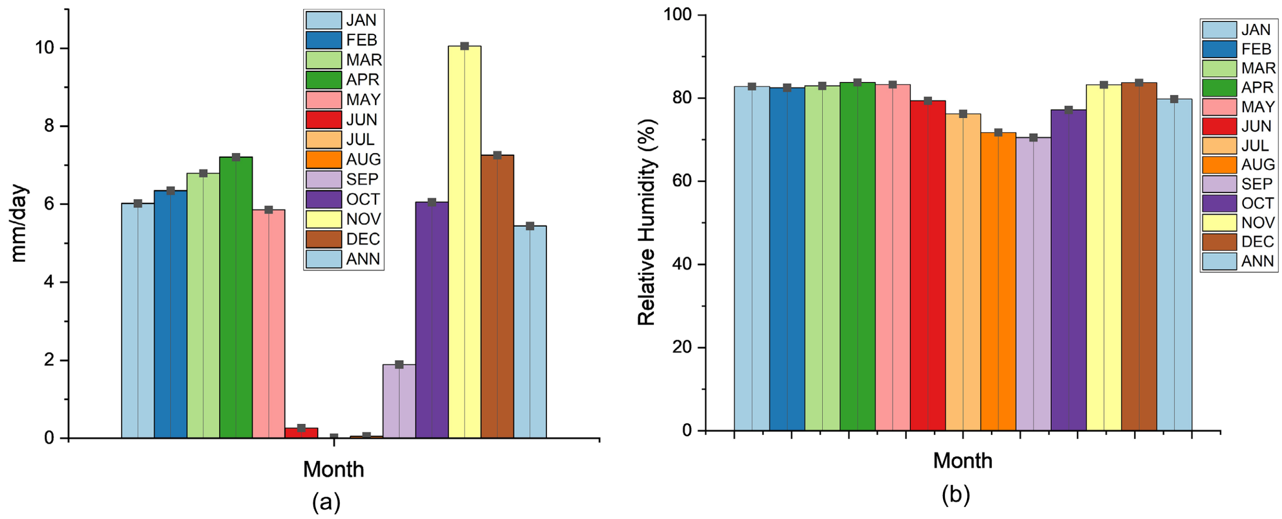


Figure 6. Monthly average precipitation in Kinshasa from 1981 to 2022 in mm/day (a), monthly average relative humidity in Kinshasa from 1981 to 2022 in mm/day (b).

3.2. Sources of Water Contamination in the Study Area

Among the many difficulties REGIDESO faces is pollution. The N'djili River faces pollution from both home and industrial sources, making the task of treating the water more difficult. Infrastructure: The authority confronts difficulties with maintaining and updating its infrastructure. Waste, chemicals, and sewage can pollute the water, necessitating more thorough treatment. Water losses and a decline in service quality can be caused by outdated machinery and distribution network leaks, as well as rising demand. As Kinshasa's population grows, so does the demand for water, placing strain on the distribution system and necessitating ongoing expenditures to increase the service's capacity and dependability.

During the geo-environmental campaign, we explored the area, identifying probable sources of contamination of the water of the N'djili River and groundwater. We made the following observations:

- The feces waste was everywhere. People take advantage of this environment to relieve themselves due to the lack of public toilets. This activity contaminates water by bringing coliforms into it;
- Plastic waste and miscellaneous waste thrown all around the river. Solid waste is either thrown directly into the river or thrown around the river. This is due to the lack of a solid waste management system in the area;
- Highly polluted household wastewater. Domestic water is discharged into the environment without basic treatment, which poses a danger to the ecosystem;
- The channeling of toilet water directly into the river. The lack of adequate sanitation systems leads the population to pipe toilet water directly into the river, which increases coliforms in the raw river water;
- The springs are fitted out to fight against humidity in the plots. In the studied area, the aquifer is unconfined. The water is, therefore on the surface, which causes a humidity problem in homes. To do this, the population creates water

sources to release the water that stagnates in the plots;

- The agricultural zone is where certain chemical inputs are used without control. In order to increase agricultural productivity, market gardeners use chemical inputs, which are unfortunately not managed by a solid policy;
- Breeding practice: in the study area, the practice of breeding poultry, pigs, and cattle was noted. The excrement from these animals is washed away by rainwater, which infiltrates into the subsoil and flows into the river;
- The exploitation of sand in the N'djili River for construction purposes stirs up particles that have settled at the bottom of the river, which increases the level of suspended solids and turbidity in the water. River sand is preferred for making concrete because of its physical properties [20].

The following **Figure 7** presents some of the observations made in the area.

Figure 7. Feces below the N'djili bridge (a1) and (a2); Plastic waste (a3); Heavily polluted household wastewater (a4); Miscellaneous waste (b); The channeling of toilet water directly into the river (c); Developed water sources.

Figure 8 depicts the use of specific chemical inputs in agriculture (a), the raising of cattle (b), and the process of sand mining, which stirs up the sand at the river's bottom and accelerates the flow of dissolved solids and suspended particles (c).

In agricultural areas, the following products are used to increase productivity and are likely to increase the concentration of elements in groundwater and in the N'djili River:

- NPK products: these are chemical fertilizers that contain nitrogen, phosphates, and potassium. They are used as fertilizers in the form of directly assimilable soluble salts, allowing high yields to be obtained but with significant risks of leaching into groundwater and the N'djili River [31];
- The blue and red DI-GROW: these are liquid organic fertilizers that contain nitrogen, phosphates, potassium, calcium, and sulfur [32];

Figure 8. Agricultural area (a); Husbandry practice (b); Sand mining on the river (c).

- Ceftriaxone injectable ($C_{18}H_{18}N_8O_7S_3$): This product is part of the World Health Organization's list of essential medicines [33];
- IVOIRI 80 WP: It is a contact fungicide acting on many diseases. It destroys the fungus by inhibiting its respiration and energy production [34];
- Manèbe is a non-systemic fungicide used against fungal diseases, notably scabs. This substance presents chemical hazards and decomposes on contact with acids or moisture. This produces toxic and flammable gases, including hydrogen sulfide and carbon disulfide. The substance is very toxic to aquatic organisms. This substance enters the environment during normal use. Great care should, however, be taken to avoid any further release, for example, through inappropriate dumping [35]-[37];
- DD Force ($C_4H_7Cl_2O_4P$) is an insecticide used in agricultural areas. DD-Force contains dichlorvos, which is classified by the WHO as a very hazardous chemical (Class Ib) [38]. The results of the study by authors Nwankwo *et al.* in 2017 [39] demonstrate that acute exposure to DD-Force has the potential to promote kidney damage;
- DDT ($C_{14}H_9Cl_5$) has been used as an insecticide to prevent the spread of disease and to protect crops. The substance is very toxic to aquatic organisms. This substance may be dangerous for the environment. Particular attention should be paid to birds. Bioaccumulation of this chemical can occur throughout the food chain, for example, in milk and aquatic organisms. This substance enters the environment during normal use. Great care should, however, be taken to avoid any further release, for example, through inappropriate dumping [36] [40].

The chemical inputs mentioned above are represented in the following **Figure 9**.

Figure 9. NPK products (a); DIGROW blue (b1) and red (b2); Ceftriaxone injection (c); IVOIRI 80 WP (d); DD Force (e).

3.3. Water Vulnerability Analysis

Carrying out a water vulnerability analysis consists of evaluating the interaction between human activities around the catchment and/or water pumping areas by delimiting the protection perimeters and making an occupation plan there. To do this, we have established the immediate protection perimeter, which is an area where all activities are prohibited except those relating to the operation and maintenance of the water catchment structure and the perimeter itself [41]. The close protection perimeter, which represents a larger area for which any activity likely to cause pollution is prohibited or is subject to special requirements (construction, deposits, discharges, etc.), and finally, the distant protection perimeter, which remains optional.

3.3.1. Case of Surface Water: N'djili River

We will therefore take 500 m upstream and 50 m downstream of the catchment point, including 10 m of strips of land from the highest watermark, for the immediate protection perimeter (**Figure 10(a)**); 10 km upstream and 50 m downstream of the sampling site, including 120 m of strips of land from the highest watermark (**Figure 10(b)**), for the close protection perimeter and the entire basin for the protection perimeter (optional) [42].

In the immediate and close protection perimeters, several activities have a negative impact on water quality. In the immediate area, human activities are the basis for discharges of domestic wastewater and industrial products; Discharges of solid waste from commercial activities; road traffic is also observed, as are the pipelines of the Services of Congolese Oil Companies (SEP Congo).

Within the close protection perimeter, human activities are classified as follows: domestic and industrial activities: They are the basis of wastewater discharges, public landfills (plastics, pharmaceutical products, wood, etc.), discharges of industrial process water loaded with pollutants, discharge of solid industrial waste; agricultural activities: Produce fertilizers, phytosanitary products, manure spreading, etc.; Commercial activities: they are the basis of wastewater discharges, solid waste, public landfills, the extraction of sand from the river, oils and hydrocarbons, the storage of dangerous products, the transport of hydrocarbons (SEP Congo pipelines); Road transport: Transport of dangerous products, dispersion of organic and inorganic micropollutants, flight of dust and metallic trace elements.

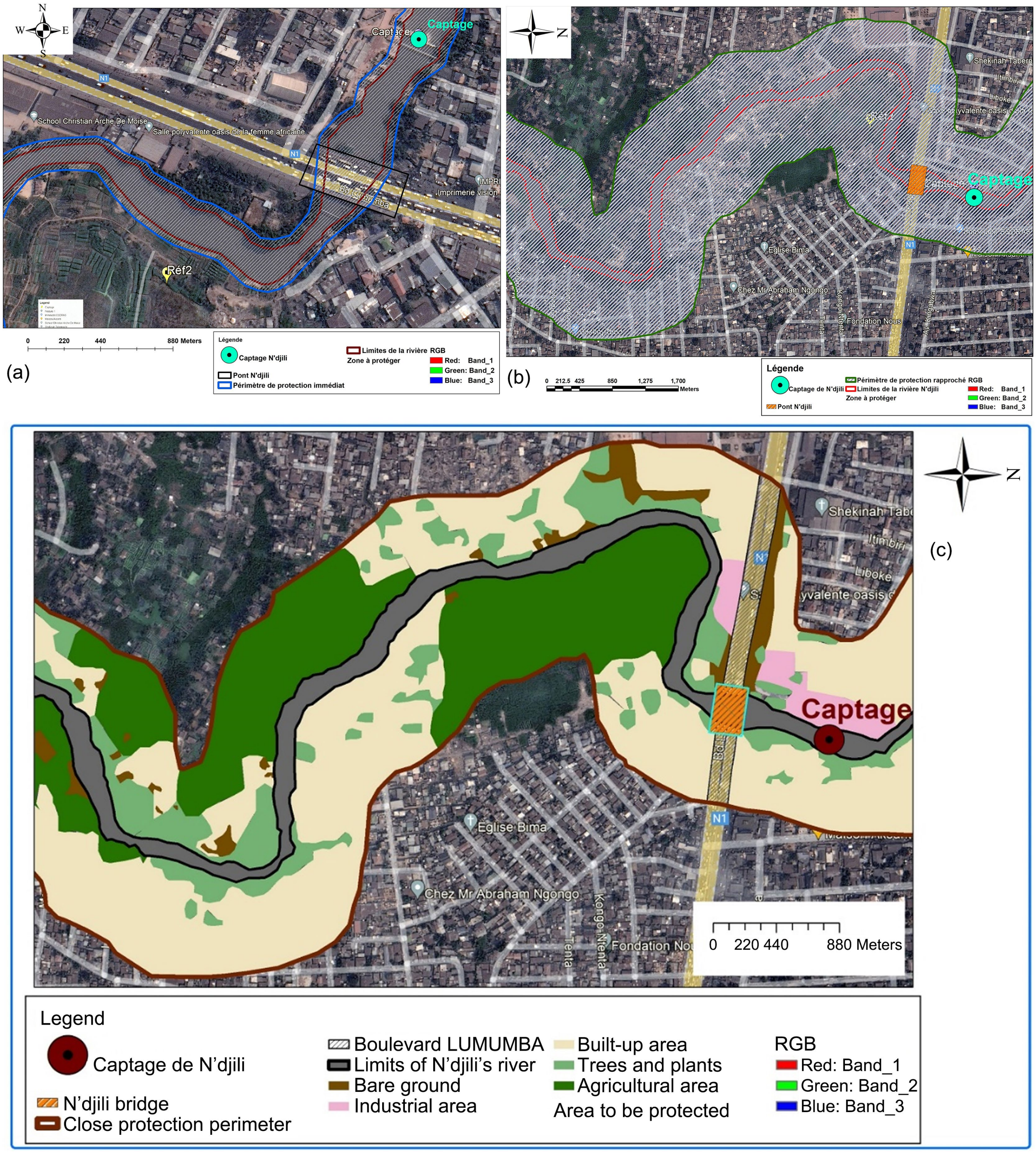


Figure 10. Excerpts from the delimitation of the immediate protection perimeter (a) and the close protection perimeter (b), extract of occupation of the immediate and close protection perimeters (c).

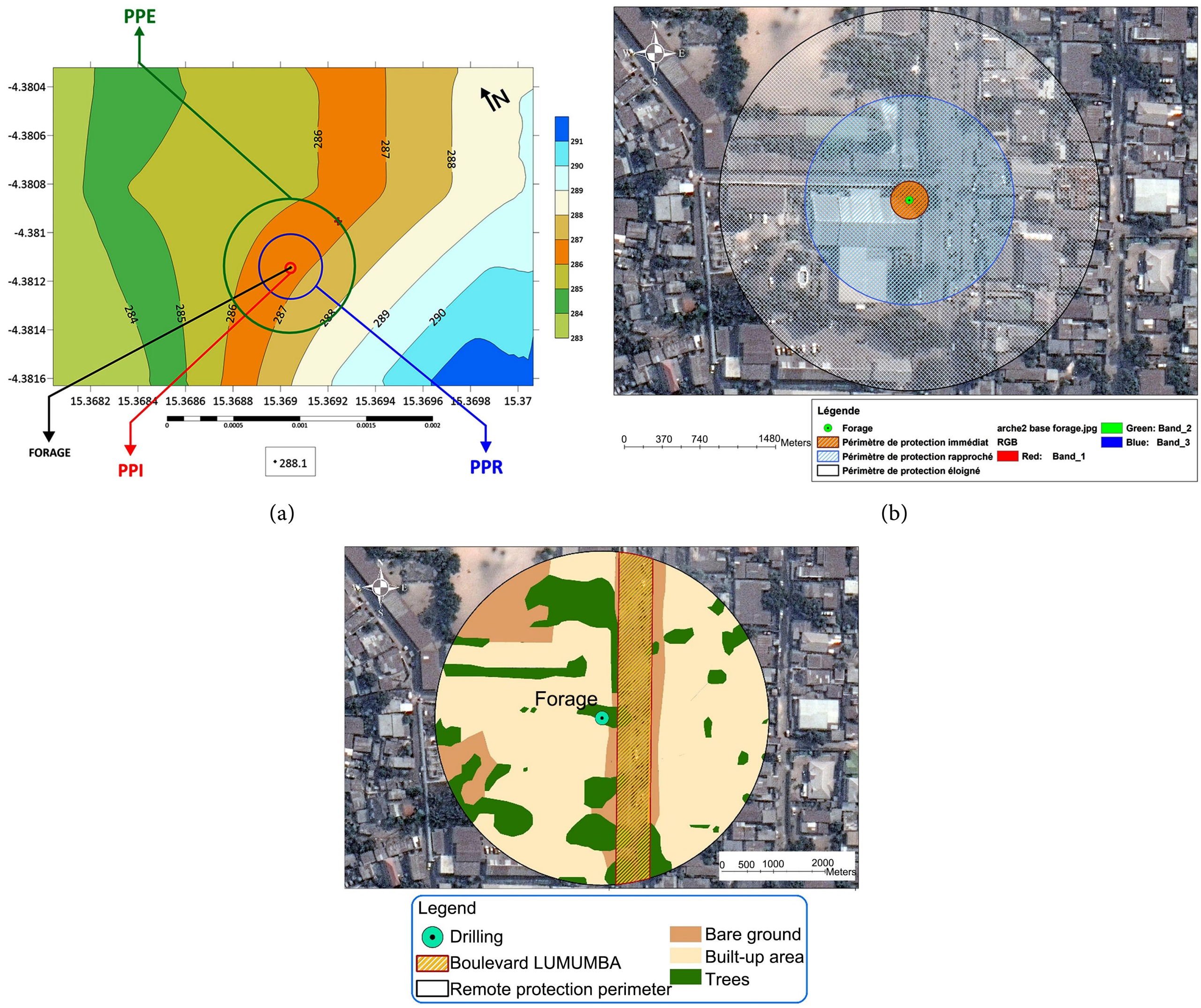
Figure 10 below shows the occupation of the immediate and close protection perimeters.

3.3.2. Case of Groundwater: Water Exploitation Drilling

The protection perimeters of a borehole in the event that we do not have hydrogeological data are as follows:

- A circle of 5 m radius for the immediate protection perimeter;
- A circle of 50 m radius (minimum) for the close protection perimeter;
- A circle of 100 m radius for the remote protection perimeter [43].

By applying these values, we have the Figure 11(a). Figure 11(b) presents the occupancy plan of the borehole protection perimeters using the supervised classification method. A large part is occupied by dwellings, followed by vegetation (trees and wild plants), bare soil, and road traffic.



(a) (b) (c)

Figure 11. Delimitation of the protection perimeters of the FLM1 borehole with contour lines (a) and direct terrain model (b), occupation of drilling protection perimeters (c).

The results of the work of Mufungizi *et al.* in 2024 [2] present abnormal levels of nitrates in the groundwater, which in turn contaminates the river. It was also noted that the quantity in mg/l of iron in the raw water of the river far exceeds the standard set by the WHO. It is the same for color. Nitrates in water come from agricultural areas where NPK products are used in an unregulated manner. This excess iron is regularized during the treatment process of water intended for human consumption during the clarification phase by injecting alumina sulfate into the water. The presence of coliforms in raw water from the N'djili River and in certain groundwater samples analyzed by Mufungizi *et al.* is explained by the lack of a sanitation system, which means that wastewater from toilets is channeled directly into the river.

3.4. Water Quality Monitoring

The visual or digital interpretation of the output image/raster formed is comparable to the Normalized difference vegetation index (NDVI). −1 to 0 - A bright surface without plant or water content, +1 - represents water content. For the second variation of the Normalized difference water index (NDWI), another threshold may be discovered that prevents producing false alerts in metropolitan areas: <0.3 - non-water, >0.3 - Water [44].

The NDWI values of the study area are shown in **Figure 12(a)** while the river values are shown in **Figure 12(b)** where the NDWI Content reaches 0.345 which is characteristic of water. NDWI results around the river show values up to 0.048 in the urban part, evidence of a flood zone with high humidity.

This comprehensive global model [45] allows us to compare its performance to actual water quality observations. In addition, it provides insights into regional patterns and temporal changes in TDS, BOD, and FC concentrations from 1980 to 2019. Total dissolved solids (TDS), biological oxygen demand (BOD), and fecal coliform (FC) are all concentrations. The routed forms of these elements (routed_TDS, routed_BOD, and routed_FC) include massive amounts of contaminants. These numbers describe pollution without regard for dilution, and so more precisely depict pollutant transit or "export" along the river network. Unfortunately, this data is not complete because it does not include narrower rivers and only covers large water courses.

In order to forecast the concentration of chlorophyll-a in estuary and coastal turbid productive waters using remote sensing data, the study of the authors *Sachidananda and Deepak* [26] suggests using the normalized difference chlorophyll index (NDCI). Images over the Chesapeake Bay, Delaware Bay, Mobile Bay, and Mississippi River delta region in the northern Gulf of Mexico were successfully processed using the algorithm. According to the research, NDCI can be used to identify algal blooms, monitor chl-a levels quantitatively in inland coastal and estuary waters, and qualitatively infer chl-a concentration ranges.

In two coastal estuaries in the Gulf of Mexico, the normalized difference chlorophyll index (NDCI) was utilized to calculate chlorophyll-a (chl-a) using the

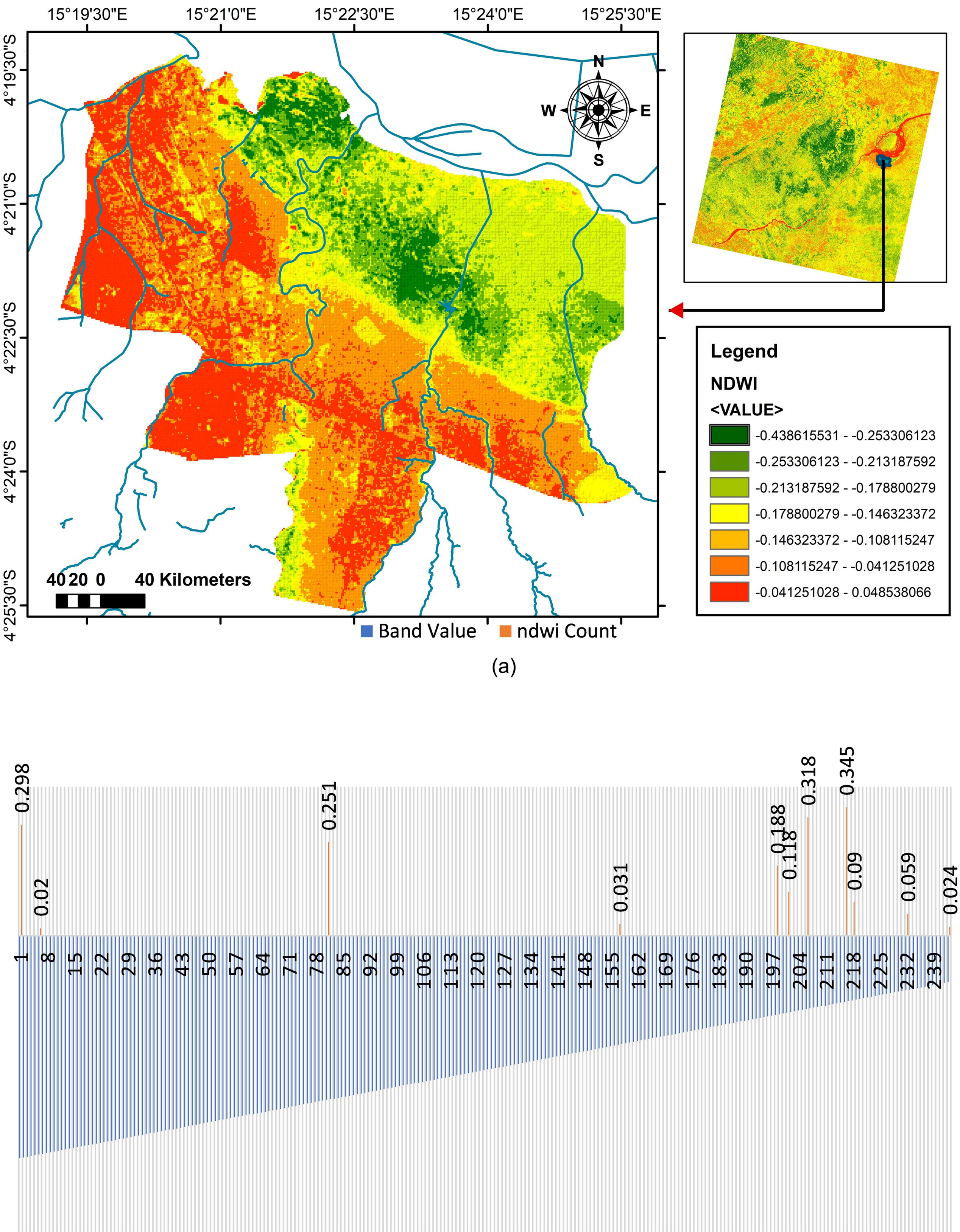


Figure 12. NDWI map of the study area (a), NDWI content of the study portion of the N'djili River (b).

Hyperspectral Imager for the Coastal Ocean (HICO) by the authors Mishra *et al.* in 2014 [46].

HyperSAS remote sensing reflectance and in situ water sample analysis provided the chl-a data. Since NDCI and chl-a have a high geographical correlation, NDCI might be used as an effective qualitative monitoring method. The following figure shows the Normalized difference chlorophyll index (NDCI) map of the study area. Around the river, we have NDCI values up to 0.2 which is a sign of the presence of chlorophiles in the river, a sign of an observable rate of dissolved solids (**Figure 13**).

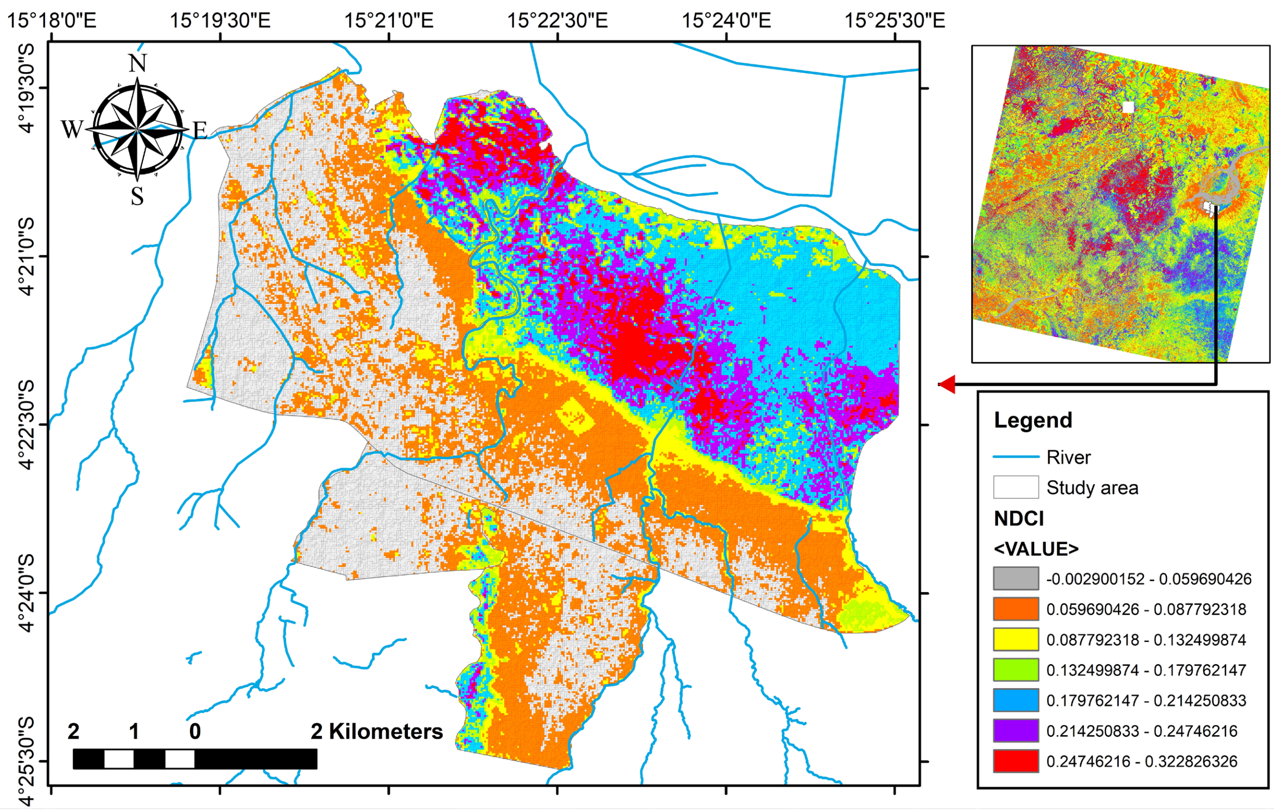


Figure 13. Normalized difference chlorophyll index (NDCI) map of the study area.

4. Conclusion and Recommendation

4.1. Conclusion

We have listed several sources of water pollution of the N'djili River as well as groundwater exploited in the area. The anthropogenic activities carried out in the protection perimeters of the N'djili River and the borehole studied are the basis of the contribution of chemical inputs and feces from warm-blooded animals. In agricultural areas, certain chemical inputs are used to increase the profitability of crops, such as NPK products, which provide nitrate, phosphate, and potassium; DIGROW; Ceftriaxone; IVOIRI; and pesticides, for example, the DD Force product, which presents dangers to human health. Wastewater is not treated before being released into nature. As a result, households discharge wastewater and toilet water loaded with feces into the river. It is therefore obvious that surface water and groundwater are vulnerable to human activities in the area around the REGIDESO water catchment on the N'djili river and require further study.

4.2. Recommendation

Considering the results, the discussion and the conclusion, we allow ourselves to formulate some following recommendations, first for the study area, also useful for the whole national territory: Strengthen regulations and binding standards regarding the use of chemical inputs in agricultural areas; identification and monitoring of market gardeners on how they are handled; sensitization of the population to the risks associated with the uncontrolled use of phytosanitary products and fertilizers on their health; Aim for an ecological transition policy for market gardening, especially in urban areas where certain rivers are used as catchment points for the production of drinking water while strictly respecting the various protection perimeters (immediate, close and distant) throughout the rivers and think about integrated water resources management [47]; Stop with certain practices not mastered and not approved by the competent entities of some products such as AQUA, CHLOROKINE for the home treatment of groundwater, or even those treated by REGIDESO; Any abstraction of groundwater (source or borehole) must require a hydrogeological investigation carried out by a professional hydrogeologist; Adopt an urban development system by highlighting an architecture with a sewer system to promote the channeling of household wastewater; Carry out environmental monitoring and control while prohibiting people from emptying their septic tanks in runoff water during heavy rains; Build public toilets at affordable prices to avoid contamination of water by feces, for example under the N'djili bridge where people relieve themselves easily, infecting the water of the river; Environmental monitoring using GIS and Remote sensing-based methods [48], monitoring of pipes and repairing of leaks to prevent exchanges between groundwater and treated water, which would limit the contamination observed.

Conflicts of Interest

The authors declare no conflicts of interest.

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