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Amazon Water Resources Utilization and Protection Mechanism

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Abstract: The Amazon Basin, a cornerstone of global ecology, is grappling with the conflict between water resource development and ecological protection. With booming economic activities like agriculture and hydropower projects, its delicate ecosystem is under threat. This thesis explores the use of green and blue water to mitigate pollution and drought caused by agricultural water use in the southeastern part of the Amazon region and to increase agricultural production. Key issues include water lack due to agricultural expansion, ecological damage from deforestation, and increased droughts linked to changing climate patterns. The study underscores the importance of implementing water use strategies that balance blue and green water to ensure sustainable agriculture and protect ecosystems. The findings suggest that precision irrigation, rainwater harvesting, and optimized water management are crucial for maintaining ecological stability and adapting to the challenges posed by climate change.

Keywords: Amazon Basin, Water resources, Climate change, Blue water and Green Water Applications, Sustainable agriculture

1. Introduction

The Amazon Basin, spanning 9 South American nations, covers 7M km² and hosts immense biodiversity. Critical for global ecology and water, it sustains 34M people. Agricultural water demand has surged, causing overuse and waste. Deforestation and farming shrank rainforests—80,000 fires in 2019 alone—disrupting ecosystems, endangering species, and worsening droughts.

Balancing agricultural water use and ecology is vital. Theoretically, it advances ecological economics and sustainability. Practically, it guides water-efficient, eco-friendly farming, boosting local economies and protecting habitats. Globally, it aids climate change mitigation, species conservation, and offers solutions for regions facing similar crises.

This study analyzes southeastern basin data—economic, environmental, and social—using literature and case studies. It assesses water resource and ecological trends, identifies gaps, and examines local water use, conservation efforts, and challenges. The goal: craft universal strategies to balance blue and green water, ensuring sustainable development.

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2. Amazon water resources utilization and protection mechanism

2.1. The crucial role of the Amazon Basin in the global context and its current state of pollution

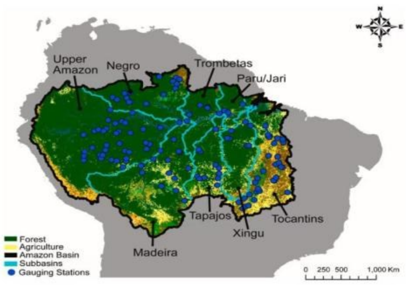

Figure 1: The area through which the Amazon River flows [1]

The Amazon Basin, often referred to as the “lungs of the Earth”, is an incredibly vital ecosystem for the planet.

Figure 1 depicts the Amazon Basin. The green areas represent forests, which are the dominant land-cover type. Yellow areas indicate regions used for agriculture, showing human impact on the landscape. Blue lines mark the sub-basins, with major river systems like the Negro, Tapajos, and Xingu labeled. Blue dots are gauging stations for monitoring water levels and flow. This map is useful for studying hydrology, environmental changes, and the balance between natural and agricultural uses in the Amazon.

2.1.1. The Amazon Basin as a global water resource

The Amazon River and its tributaries drain roughly 6.1 million square kilometers, making it the largest river basin on Earth [2]. As the largest fresh water system globally, the Amazon Basin is an essential source of water for many regions, influencing ecosystems far beyond South America.

2.1.2. The Amazon's ecological and climatic influence

The Amazon also has an indispensable role in regulating the Earth's climate. The vast forest within the basin absorbs large quantities of carbon dioxide, acting as a carbon sink and mitigating climate change.

2.2. Pollution and disasters afflicting the Amazon Basin in recent years

In recent decades, the Amazon Basin has faced increasing pressures from human activities, resulting in pollution and environmental disasters that threaten its delicate ecosystem [3].

2.2.1. Types of pollution in the Amazon Basin

The Amazon Basin faces several types of pollution, including deforestation, industrial waste, and agricultural runoff.

2.2.2. Natural and human-induced disasters

Both natural and human-induced disasters have contributed to the environmental degradation of the Amazon. Floods, droughts, and forest fires are common natural disasters that disrupt the Amazon's water systems. However, human-induced disasters, such as large-scale deforestation and illegal

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mining, exacerbate the damage [4]. Forest fires, in particular, have become increasingly frequent, often set deliberately to clear land for agriculture.

3. The impact of agricultural water use on the Amazon

Recent studies show that agricultural water usage in the Amazon basin accounts for a considerable portion of the region's total water use. For instance, in northern and southeastern Brazil, the demand for agricultural irrigation has increased significantly, especially for crops such as soybeans, sugarcane, and coffee [5].

Furthermore, over-extraction of water for agriculture has disrupted the hydrological cycle of the ecosystem, damaging the water balance in the Amazon basin. Studies show that excessive blue water usage and improper green water management have led to local ecological imbalances, affecting the overall climate patterns of the basin [6].

3.1. Agricultural expansion and water resource depletion

Agricultural expansion, particularly for crops like soybeans, maize, and palm oil, has led to widespread land conversion and water resource depletion in the Amazon. Large-scale irrigation systems used in agriculture extract enormous amounts of water from rivers and groundwater, reducing the availability of water for both ecosystems and human communities. The high-water consumption associated with these crops, coupled with the changing landscape, has put immense pressure on the basin's freshwater resources.

3.2. Sustainable agricultural practices and water management

To mitigate the negative impact of agricultural water use, sustainable farming practices are crucial. Agroforestry, which integrates trees with crops and livestock, can help maintain soil moisture and reduce the need for irrigation. Additionally, implementing efficient irrigation systems that minimize water waste can play a significant role in conserving water resources. By promoting sustainable farming practices, it is possible to strike a balance between agricultural production and the protection of the Amazon's vital water resources.

4. The importance of correct application of blue and green water

Understanding and managing water resources in the Amazon requires distinguishing between two types of water: blue water and green water [7]. Both are essential for sustaining ecosystems and agriculture, yet their management plays a critical role in ensuring water sustainability.

4.1. Definition and differences between blue and green water

Blue water refers to the water found in rivers, lakes, and aquifers, which is used for irrigation, industrial processes, and human consumption. Green water, on the other hand, is the water stored in soil and vegetation, which is used by plants for growth through processes like transpiration. Both types of water are crucial for maintaining the balance of the Amazon's water cycle [8].

4.2. Implications of mismanagement of water resources

Mismanagement of blue and green water can lead to severe consequences, including water scarcity, soil degradation, and loss of biodiversity. For example, over-extraction of blue water can lead to reduced river flow and drying up of water sources, while improper use of green water can lead to soil erosion and reduced agricultural productivity. Effective water management is essential to ensure that

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both blue and green water are used sustainably, protecting the long-term viability of the Amazon ecosystem and the communities that depend on it.

5. The application of blue and green water in the Amazon Basin

In addressing the sustainable use of water resources in the Amazon Basin, both green water and blue water management are crucial for fostering environmental resilience, supporting agricultural productivity, and promoting long-term ecological stability. Below, this study explores targeted strategies for the effective management of green and blue water, accompanied by quantitative analysis and proposed measures.

5.1. Green water management: harnessing natural systems for water conservation

Green water, defined as the water stored in the soil and used by plants, plays a pivotal role in sustaining the Amazon's ecosystems and agricultural practices. Managing this resource effectively is key to enhancing soil moisture, reducing water runoff, and promoting biodiversity. The following strategies are essential for optimizing the use of green water:

5.1.1. Planting native deep-rooted trees

One of the most effective ways to conserve green water is through the strategic planting of native deep-rooted trees, such as Brazil nut trees (Bertholletia excelsa) [9]. These trees not only help in storing water but also serve as natural filters, reducing pollution and promoting the local water cycle by boosting rainfall. Studies suggest that for every hectare of Amazonian-forest restored, approximately 200-300 mm of water can be stored in the soil annually. Furthermore, these trees help mitigate the risk of droughts by maintaining a steady flow of moisture through the soil.

5.1.2. Promoting rainwater collection systems

Implementing rainwater harvesting strategies is a cost-effective way to supplement water availability in rural and peri-urban areas. A typical rainwater collection system can provide 30%-40% of the water needed for daily household activities in regions with average annual rainfall exceeding 1,500 mm [10]. Additionally, larger-scale rainwater storage infrastructure could be constructed to capture rainfall during the wet season, ensuring sufficient water for dry-season agricultural needs and emergency situations.

5.2. Blue water management: ensuring sustainable water use for agriculture and industry

Proper management of blue water resources is necessary to prevent over-exploitation, enhance water-use efficiency, and preserve aquatic ecosystems. Key strategies for improving the management of blue water in the Amazon Basin include:

5.2.1. Establishing a basin-wide water management agency

A proposed regression model for assessing the relationship between seasonal water availability and water allocation efficiency could look as follows:

$$\text{Water Allocation Efficiency (WAE)}\} = \beta_0 + \beta_1 . \times X_1 + \beta_2 \times X_2 + \varepsilon \tag{1}$$

Where:

- WAE represents the efficiency of water use across sectors.
- X_1 is the amount of rainfall in the region (mm).

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- X_2 is the total water demand by sector (m^3).
- β_0, β_1, β_2 are the regression coefficients.
- ε is the error term

5.2.2. Upgrading sewage treatment and reusing water

Upgrading sewage treatment facilities in urban areas and industrial zones is essential for improving water quality and reducing pollution [10]. Implementing advanced wastewater treatment technologies allows the reuse of treated water for non-potable purposes such as irrigation, industrial cooling, or urban landscaping.

5.2.3. Promoting water-saving irrigation technologies

Efficient irrigation practices, such as drip irrigation and micro-sprinkler systems, can drastically reduce water waste. These technologies deliver water directly to plant roots, minimizing evaporation losses and ensuring that crops receive only the water they need. Implementing smart irrigation systems, equipped with sensors to monitor soil moisture levels and weather forecasts, can further optimize water use [11].

Table 1: Showing the efficiency of blue and green water use and the reduction in water waste for five different methods

No.	Method	Blue water efficiency (%)	Green water efficiency (%)	Reduction in Water Waste (%)
1	Planting Deep-Rooted Trees	85	80	20
2	Rainwater Collection	90	75	25
3	No-Till Farming	80	90	30
4	Water Management Agency	75	70	15
5	Drip Irrigation	95	85	40

Table 1 compares five water-management methods on blue (surface/groundwater) and green (evapotranspiration) water efficiency and waste reduction. Planting Deep-Rooted Trees achieves 85% blue and 80% green water efficiency, cutting waste by 20%. Rainwater Collection outperforms with 90% blue water efficiency and 25% waste reduction, proving its water-conserving strength. No-Till Farming scores 90% green water efficiency and 30% waste cut, highlighting sustainable water use.

The Water Management Agency lags with 15% waste reduction. Drip Irrigation excels, offering 95% blue water efficiency and 40% waste reduction. These results highlight the need for advanced techniques in regions like the Amazon Basin, where sustainable water management sustains ecological balance and agriculture.

6. Conclusion

This paper has explored the utilization and protection mechanisms of water resources in the Amazon Basin, focusing on the delicate balance between agricultural development and ecological preservation. By analyzing both literature and case studies, we identified the significant challenges posed by human activities, such as deforestation, agriculture, and industrial water use, which disrupt the natural hydrological cycles of the region. The study emphasizes the importance of balancing blue water

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(surface and groundwater) and green water (evapotranspiration) in order to maintain sustainable agriculture and preserve the ecosystem.

Our findings underscore that the overuse of blue water for irrigation has led to reductions in river flows and groundwater levels, while the sustainable use of green water can reduce dependency on blue water and help maintain ecological balance. By incorporating efficient water management strategies such as rainwater harvesting and precision irrigation, the Amazon region can mitigate water scarcity and ensure long-term agricultural and ecological stability. Additionally, the paper highlights the need for integrated water management policies that consider both environmental and socio-economic factors.

However, the research has some limitations. The case studies were limited to certain regions in the southeastern part of the Amazon, and broader regional data could provide a more comprehensive understanding. Additionally, while the paper focuses on theoretical frameworks and strategies, more empirical research on specific agricultural practices and their direct impact on water resources is needed. Future research could further explore the practical application of blue and green water management in agricultural settings, with a particular focus on developing sustainable, green agriculture practices that reduce environmental degradation while increasing food production. This would be crucial for addressing the long-term impacts of climate change and ensuring the Amazon's ecological and agricul resilience

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