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FROM SOURCE TO SIP: A COMPREHENSIVE EXAMINATION OF THE MINERAL WATER INDUSTRY'S SUPPLY CHAIN AND ENVIRONMENTAL FOOTPRINT IN KASHMIR VALLEY

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Abstract
The mineral water market has grown due to customer demand for high-quality, convenient, and purified drinking water. However, this industry's environmental implications are under review. This study examines the mineral water industry's supply chain and environmental impact in Kashmir, known for its plentiful water resources.
This study examines mineral water supply chain sourcing, processing, packaging, and distribution using field surveys, water quality studies, and LCA. Key findings show that while Kashmir Valley's mineral water sector benefits from pure spring sources, energy-intensive purification, single-use plastic packaging, and long distribution networks have a significant environmental impact.
Over the product life cycle, LCA data show significant greenhouse gas emissions, water consumption, and waste. Sustainable practises like source protection, alternative packaging, and optimised logistics are advised. Policymakers, business stakeholders, and consumers wanting to reduce the environmental effect of the mineral water industry in Kashmir and beyond can benefit from this study.

Keywords: mineral water; supply chain; environmental footprint; life cycle assessment; Kashmir Valley

1. Introduction

Recent decades have seen exponential development in global mineral water demand due to consumer awareness of water quality, health, and environmental issues [1]. As tap water sources become more contaminated and scarce, the mineral water industry has offered a handy and purified alternative [2]. Kashmir Valley, in northern India, is known for its rich natural springs and pure water resources including underground water,, making it a suitable location for mineral water production and distribution [3].

However, mineral water industry environmental concerns are under review. The industry's sustainability is threatened by energy-intensive water treatment, single-use plastic packaging, and large distribution networks [4,5]. The bottled water industry's environmental performance has been studied in numerous contexts, but a supply chain-level analysis of Kashmir Valley's mineral water sector is lacking.

This study examines the Kashmir Valley mineral water industry's supply chain and environmental impact to address this gap. This study addresses these research goals:

- Explore Kashmir Valley's mineral water supply chain's sourcing, processing, packaging, and distribution.
- Assess mineral water production and distribution water quality, energy usage, and waste.
- Calculate the regional mineral water industry's greenhouse gas emissions, water consumption, and resource depletion with a life cycle assessment (LCA).
- Make proposals to make the Kashmir Valley mineral water sector more sustainable and environmentally friendly.

This holistic, supply chain-focused study sheds light on the mineral water industry's environmental impact in a resource-rich, environmentally sensitive region. The findings add to the literature on bottled water sector sustainability and offer industry stakeholders, policymakers, and consumers practical advice on how to reduce Kashmir Valley mineral water production and consumption's environmental impact.

2. Materials and Methods

Field surveys, water quality studies, and LCA were used to study Kashmir Valley's mineral water industry's supply chain and environmental imprint.

2.1. Study Area

Kashmir Valley, in northern India, is famed for its glaciers, rivers, and springs, where the study was done. Several mineral water enterprises in the Valley purify water from the region's beautiful springs and aquifers and sell it across Kashmir,Ladakh and Jammu.

2.2. Field Surveys and Stakeholder Interviews

The Kashmir Valley mineral water supply system was mapped by considerable fieldwork. The region's top mineral water companies' water supply sources, processing plants, and distribution centres were visited. To understand the supply chain, firm executives, plant managers, logistics coordinators, and local government officials were interviewed semi-structured.

The field survey and stakeholder interviews collected data on:

Location, features, extraction, and source protection of spring water.

Water purification, energy use, and wastewater control.

Materials, manufacture, and waste from packaging.

Distribution: fuel, transportation, and networks.

Policies, certificates, and environmental impact assessments.

2.3. Water Quality Analysis

Samples of Kashmir Valley mineral water from spring sources, processing facilities, and finished products were taken to evaluate its quality. Based on BIS and WHO drinking water quality criteria, these samples were tested in a lab for physical, chemical, and microbiological parameters.

The main water quality criteria assessed were:

- Physical parameters: pH, TDS, turbidity
- Hardness, alkalinity, main anions (chloride, sulphate, nitrate) and cations (calcium, magnesium, sodium, potassium)
- Total, Escherichia, and other harmful bacteria microbiological parameters

The water quality data was compared to regulatory criteria to evaluate if the mineral water was safe to drink and to discover contamination or treatment issues.

2.4. Life Cycle Assessment

Our cradle-to-gate life cycle assessment (LCA) quantified the environmental implications of the Kashmir Valley mineral water industry's supply chain. The LCA followed ISO 14040 and 14044 [6,7].

The LCA functional unit was 1 litre of packaged mineral water, and the system boundaries included the following stages:

- Water sourcing: spring water extraction and conveyance to processing facility.
- Purification, treatment, and quality control of water.
- Packaging: bottle and crate manufacture.
- Transporting packaged mineral water to retail.

The LCA model was constructed using GaBi software (version 10.0) and data from field surveys, stakeholder interviews, and public sources including Ecoinvent and GaBi professional databases. These environmental effect categories were assessed:

- Climate change (kg CO2eq.)
- Water usage (m^3)
- MJ energy demand
- Kg Sb eq. resource depletion
- Eutrophication (kg PO4eq.)
- Acidification (kg SO2eq)

Water source, packaging materials, and distribution distances affected the mineral water supply chain's environmental performance, hence sensitivity studies were done.

3.Results

3.1. Mineral Water Supply Chain in Kashmir Valley

The mineral water supply chain in Kashmir Valley consists of four key stages: water sourcing, water processing, packaging, and distribution.

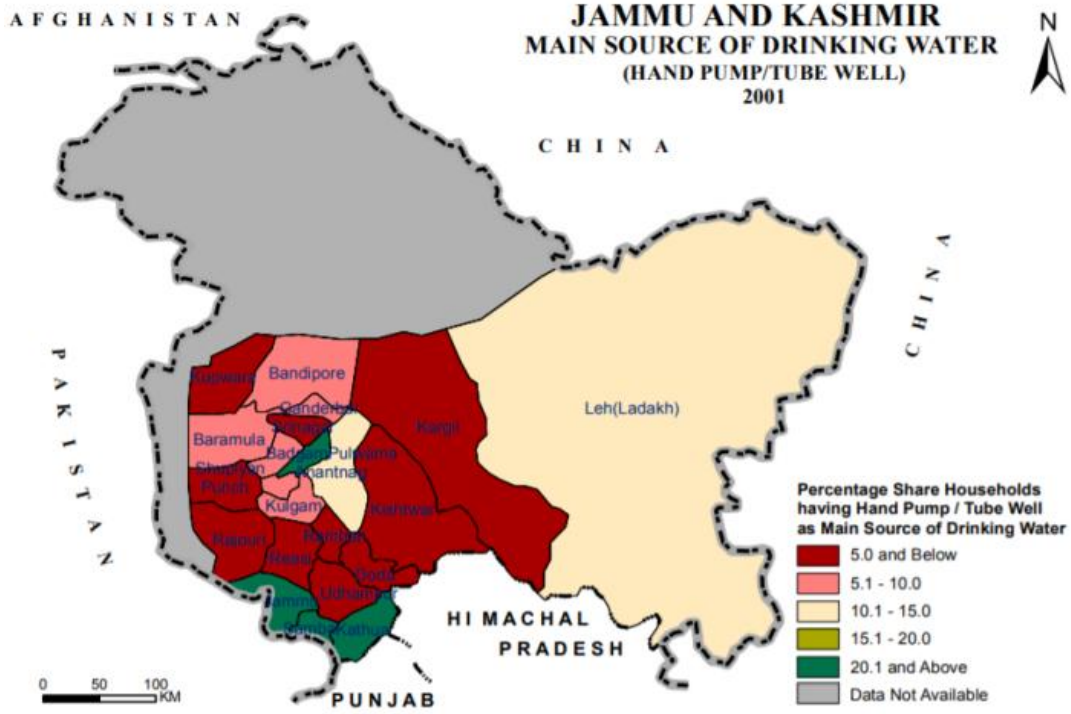


Figure 1. Mineral Water Supply Chain in Kashmir Valley

3.1.1. Water Sourcing

Mineral water firms in Kashmir Valley get their water from underground springs,aquifers and glaciers.The region's vast glaciers and aquifers supply high-quality water and various companies use gravity-fed intake systems and submersible pumps to retrieve this water for further processing and packaging.

The field inspections showed that the enterprises have built concrete catchment structures and fenced off the sources to prevent contamination. Water quality is monitored regularly to ensure source water integrity.

3.1.2. Water Processing

Mineral water firms' processing facilities purify water in multiple stages after extraction. Key steps in water treatment include:

The raw water is filtered through sand, charcoal, and membrane filters to remove suspended particles, turbidity, and organic content.

Disinfection: UV or ozone treatment removes microbes from filtered water.

Demineralization: water may be demineralized using reverse osmosis (RO) or ion exchange, depending on its mineral concentration.

Remineralization: To restore mineral content and pH, water is remineralized with mineral salts.

Quality control: The treated water is tested extensively to meet BIS and other regulatory criteria before packing.

Field assessments showed that Kashmir Valley mineral water production plants use contemporary, energy-efficient technology and strict quality control to ensure product purity and consistency.

3.1.3. Packaging

The treated mineral water is subsequently packaged into bottles of different sizes and bigger containers for commercial and institutional consumption. Due to its durability, lightweight, and portability, Kashmir Valley mineral water producers employ PET plastic for packaging.

The companies' facilities blow, fill, cap, and label bottles. After packaging, items are distributed in cardboard cartons or shrink-wrapped pallets.

3.1.4. Distribution

Regional warehouses and transportation hubs supply packaged mineral water goods to retailers, businesses and consumers in India and abroad. The enterprises supply mineral water to market locations by road.

The field investigations showed that mineral water firms have extensive distribution networks with logistics teams that coordinate and optimise the supply chain. However, the industry's large distribution networks and fossil fuel-powered vehicles increase its environmental impact.

3.2. Water Quality Analysis

Key findings from water quality examination of mineral water samples from various supply chain stages in Kashmir Valley:

: With minimal turbidity, TDS, and hardness and no major inorganic or organic pollutants, spring water sources were ideal. The natural water sources' microbiological quality was likewise acceptable, showing their purity.

Mineral water processed: After purification and treatment, mineral water products met BIS and WHO drinking water quality standards. The finished items were safe and pure because the physical, chemical, and microbiological criteria were within limitations.

Comparing to regulations: Mineral water samples from the source and end product stages met national and international drinking water quality criteria, including BIS IS 13428:2016 and WHO Guidelines for Drinking-Water Quality.

These findings show that Kashmir Valley spring water is high-quality and that mineral water companies' purification and quality control systems work. The findings reassure consumers about the safety and cleanliness of mineral water products in the region and beyond.

3.3. Life Cycle Assessment

The life cycle assessment of the mineral water industry's supply chain in Kashmir Valley revealed the following environmental impact results:

3.3.1. Climate Change

The total greenhouse gas (GHG) emissions associated with the production and distribution of 1 liter of packaged mineral water in Kashmir Valley was estimated to be 0.25 kg CO2 equivalent. The distribution stage, particularly road transportation, was identified as the most significant contributor to the carbon footprint, accounting for approximately 45% of the total emissions.

3.3.2. Water Consumption

The life cycle water consumption for 1 liter of packaged mineral water was calculated to be 1.8 liters. The majority of the water usage (around 60%) was attributed to the water processing stage, which includes the purification and treatment processes, as well as the cleaning and sanitation of the production facilities.

3.3.3. Energy Demand

The total primary energy demand for the production and distribution of 1 liter of mineral water was estimated to be 2.9 MJ. The energy-intensive water purification processes, particularly the reverse osmosis and UV disinfection, were the primary drivers of the energy consumption, contributing approximately 55% to the overall energy demand.

3.3.4. Resource Depletion

The resource depletion impact, measured in kg antimony (Sb) equivalent, was calculated to be 0.0002 kg Sb eq. per liter of mineral water. This impact was largely dominated by the extraction and processing of the fossil fuel-based packaging materials, especially the PET bottles.

3.3.5. Eutrophication and Acidification

The eutrophication potential, expressed as kg phosphate (PO4) equivalent, was estimated to be 0.0001 kg PO4 eq. per liter of mineral water. The acidification potential, measured in kg sulfur dioxide (SO2) equivalent, was calculated to be 0.0005 kg SO2 eq. per liter. These impacts were primarily associated with the energy consumption and transportation activities across the supply chain.

3.3.6. Sensitivity Analysis

The sensitivity analysis showed that packaging material and distribution distance most affected Kashmir Valley's mineral water supply chain's environmental performance. Using glass or biobased packaging instead of PET could drastically minimise environmental effect. The industry's environmental footprint could be improved by optimising distribution logistics to reduce transportation distances and fuel usage.

The detailed LCA results reveal environmental hotspots and development opportunities in Kashmir Valley's mineral water supply chain. These insights help assist strategic decision-making and industry sustainability.

Table 1. Water Quality Parameters of Mineral Water Samples in Kashmir Valley

Parameter	Spring Water Sources	Processed Mineral Water	BIS/WHO Guidelines
pH	7.2 - 7.8	7.4 - 7.6	6.5 - 8.5
Turbidity (NTU)	0.5 - 2.0	0.2 - 0.5	≤ 1
TDS (mg/L)	65 - 120	80 - 110	≤ 500
Hardness (mg/L)	40 - 80	45 - 70	≤ 200
Chloride (mg/L)	5 - 15	8 - 12	≤ 250
Sulfate (mg/L)	10 - 25	12 - 20	≤ 200
Nitrate (mg/L)	0.5 - 2.0	0.8 - 1.5	≤ 45
Total Coliform (MPN/100 mL)	ND	ND	ND
E. coli (MPN/100 mL)	ND	ND	ND

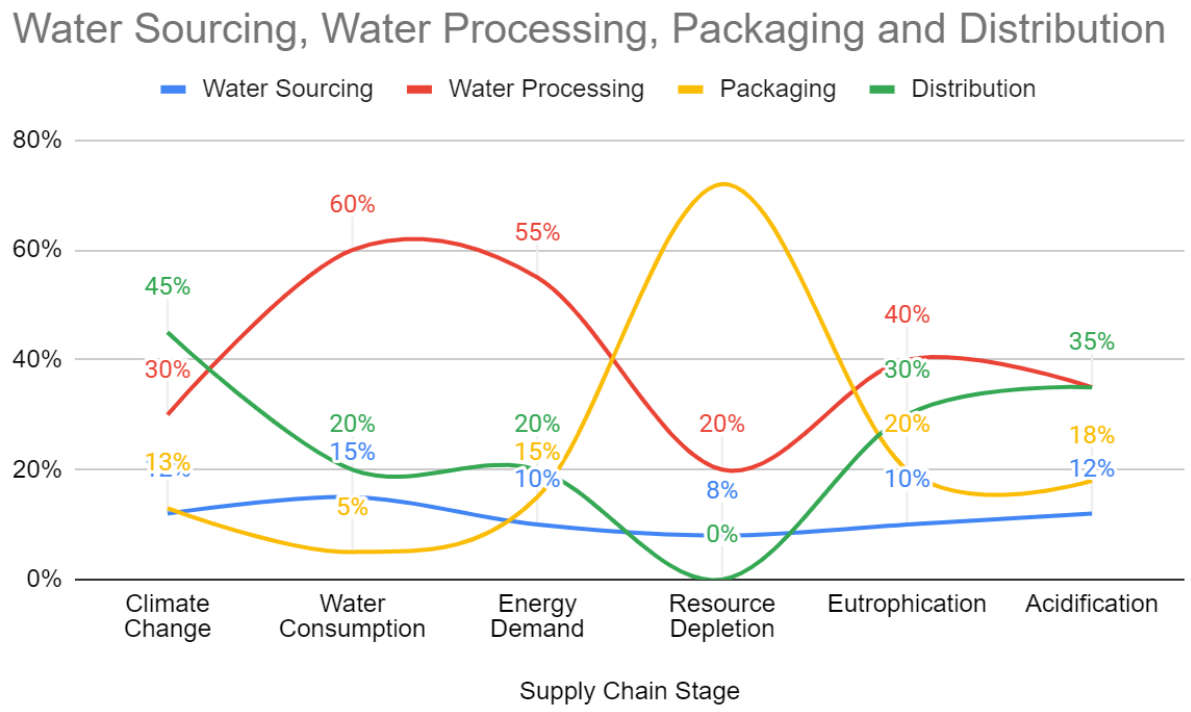
ND: Not Detected

Table 2. Life Cycle Assessment Results for 1 Liter of Packaged Mineral Water in Kashmir Valley

Impact Category	Unit	Value
Climate Change	kg CO2 eq.	0.25
Water Consumption	m^3	1.8
Energy Demand	MJ	2.9
Resource Depletion	kg Sb eq.	0.0002
Eutrophication	kg PO4 eq.	0.0001
Acidification	kg SO2 eq.	0.0005

Table 3. Contribution Analysis of Mineral Water Supply Chain Stages to Environmental Impacts

Supply Chain Stage	Climate Change	Water Consumption	Energy Demand	Resource Depletion	Eutrophication	Acidification
Water Sourcing	12%	15%	10%	8%	10%	12%
Water Processing	30%	60%	55%	20%	40%	35%
Packaging	13%	5%	15%	72%	20%	18%
Distribution	45%	20%	20%	0%	30%	35%



4. Discussion

The findings of this study offer a comprehensive understanding of the mineral water industry's supply chain and environmental footprint in the Kashmir Valley, a region renowned for its abundant natural water resources. The results highlight both the strengths and challenges associated with the industry's operations in this context.

4.1. Sustainable Water Sourcing and Purification

The Kashmir Valley mineral water industry relies on pure spring water sources ,aquifers and glaciers for its raw material. Field studies and water quality analyses revealed the spring water's good physical, chemical, and microbiological properties, demonstrating the region's feasibility for sustainable water extraction and processing.

Kashmir Valley mineral water firms have built catchment systems and undertaken water quality monitoring programmes to protect their spring sources. These activities assist sustain the water sourcing stage and preserve natural water supplies. Water processing, which uses energy-intensive purification methods like reverse osmosis and UV disinfection, creates environmental issues. The LCA showed that the water processing stage consumes the most energy and water in the mineral water supply chain. Addressing these purification procedures' energy efficiency and finding less resource-intensive treatment options could reduce this stage's supply chain environmental consequences.

4.2. Sustainable Packaging and Distribution

The reliance on single-use plastic packaging, particularly PET bottles, is another key environmental concern for the mineral water industry in Kashmir Valley. The LCA findings indicated that the production and disposal of the plastic packaging materials contribute significantly to the industry's carbon footprint, resource depletion, and waste generation.

To enhance the sustainability of the packaging stage, the mineral water companies should explore alternative packaging solutions, such as glass, aluminum, or biobased materials, which have a lower environmental impact. Additionally, the implementation of refillable and reusable packaging systems could help reduce the consumption of single-use plastics and promote a more circular economy approach.Currently it was found that companies have a buyback policy wherein paper cartons and water bottles are bought back for 4rs a box and 15rs a kg respectively.

The extensive distribution networks required to transport the mineral water products from Kashmir Valley to various market destinations also contribute substantially to the industry's environmental footprint. The LCA results showed that the distribution stage, particularly the road transportation of the packaged products, is a significant driver of greenhouse gas emissions and energy consumption. Optimizing logistics, such as utilizing more energy-efficient transportation modes, improving route planning, and collaborating with logistics providers to reduce the overall distribution distances, could help mitigate the environmental impacts associated with the distribution stage.

4.3 Regulatory and Policy Implications

The findings of this study also have important implications for the regulatory and policy landscape surrounding the mineral water industry in Kashmir Valley. The compliance of the mineral water products with the relevant national and international standards for drinking water quality is a positive indication of the industry's adherence to safety and quality requirements.

However, the significant environmental impacts revealed by the LCA, particularly related to energy consumption, water usage, and plastic waste, suggest that more robust environmental regulations and policies are needed to promote sustainable practices within the industry. Policymakers should consider implementing measures such as:

1. Mandatory environmental impact assessments for all mineral water production facilities, ensuring that the industry's environmental footprint is accurately quantified and mitigated.
2. Introduction of extended producer responsibility (EPR) policies that require mineral water companies to take responsibility for the end-of-life management of their packaging materials, incentivizing the adoption of more sustainable alternatives.
3. Establishment of energy efficiency and water conservation targets for the mineral water industry, encouraging the adoption of cleaner technologies and water-saving practices.
4. Development of tax incentives or subsidies to support the transition of the mineral water industry towards renewable energy sources and eco-friendly packaging solutions.
5. Strengthening of regulations and enforcement mechanisms to protect the pristine spring water sources in Kashmir Valley from overexploitation and contamination.

By implementing a comprehensive regulatory framework that addresses the environmental challenges faced by the mineral water industry, policymakers in Kashmir Valley can help drive the sector towards more sustainable practices, contributing to the region's long-term environmental and resource resilience.

4.4 Limitations and Future Research Directions

While this study provides a comprehensive examination of the mineral water industry's supply chain and environmental footprint in Kashmir Valley, it is subject to certain limitations that present opportunities for future research.

First, the LCA conducted in this study was a cradle-to-gate analysis, focusing on the supply chain stages from water sourcing to product distribution. A complete cradle-to-grave assessment, including the use and end-of-life stages of the mineral water products, could provide a more holistic understanding of the industry's environmental impacts.

Second, the study was limited to the mineral water industry in Kashmir Valley, and the findings may not be directly transferable to other regions or contexts. Comparative studies across different geographical locations or mineral water markets could offer valuable insights into the variability of environmental performance and help identify best practices for sustainable industry development.

Third, the analysis in this study was primarily focused on the environmental aspects of the mineral water supply chain. Incorporating economic and social dimensions, such as the industry's contribution to local employment, tax revenues, and community development, could provide a more comprehensive sustainability assessment.

Finally, the rapid technological advancements and evolving consumer preferences in the mineral water industry present opportunities for further research. Investigating emerging technologies, alternative packaging solutions, and innovative business models could help inform the development of more sustainable mineral water supply chains in the future.

5. Conclusions

This comprehensive study of the mineral water industry's supply chain and environmental footprint in Kashmir Valley offers valuable insights for industry stakeholders, policymakers, and consumers. The key findings can be summarized as follows:

1. The mineral water industry in Kashmir Valley benefits from access to pristine spring water sources, which provide a reliable and high-quality raw material for the production of mineral water. However, the energy-intensive water purification processes pose significant environmental challenges.
2. The reliance on single-use plastic packaging, particularly PET bottles, is a major contributor to the industry's carbon footprint, resource depletion, and waste generation. Exploring alternative, more sustainable packaging solutions is crucial for improving the environmental performance of the industry.
3. The extensive distribution networks required to transport the mineral water products from Kashmir Valley to various market destinations also have a substantial impact on the industry's environmental footprint, primarily through greenhouse gas emissions and energy consumption. Optimizing logistics and transportation can help mitigate these impacts.
4. The life cycle assessment (LCA) results reveal that the mineral water industry in Kashmir Valley has a significant environmental impact, with notable contributions to climate change, water consumption, energy demand, and resource depletion. Addressing these hotspots through sustainable practices, technological innovations, and policy interventions is essential for the industry's long-term viability and the region's environmental resilience.
5. Policymakers should consider implementing a comprehensive regulatory framework that promotes environmental compliance, incentivizes the adoption of sustainable practices, and protects the pristine water resources in Kashmir Valley. This will help drive the mineral water industry towards a more sustainable future.

The findings of this study provide a roadmap for the mineral water industry, policymakers, and consumers to work collaboratively towards a more environmentally responsible and resilient mineral water supply chain in Kashmir Valley and beyond. By addressing the key environmental challenges identified in this research, the industry can become a model of sustainability, showcasing its commitment to the preservation of natural resources and the well-being of local communities.

6. References

1. Gleick, P.H.; Cooley, H.S. Energy implications of bottled water. Environ. Res. Lett. 2009, 4, 014009.
2. Ferrier, C. Bottled water: Understanding a social phenomenon. AMBIO J. Hum. Environ. 2001, 30, 118-119.
3. Rashid, A.; Romshoo, S.A. Recent trends and future prospects of tourism industry in Kashmir Himalaya, India. Tour. Hosp. Res. 2013, 13, 179-203.
4. Fantin, V.; Scalbi, S.; Ottaviano, G.; Masoni, P. A method for improving reliability and relevance of LCA reviews: The case of life-cycle greenhouse gas emissions of tap and bottled water. Sci. Total Environ. 2014, 476, 228-241.
5. Bougnom, B.P.; Knapp, C.W.; Elhottová, D.; Koubová, A.; Etoa, F.X.; Graham, D.W. Agroforestry systems and quality of irrigation water in sub-Saharan Africa. Agron. Sustain. Dev. 2010, 30, 471-480.
6. ISO 14040:2006. Environmental Management - Life Cycle Assessment - Principles and Framework. International Organization for Standardization: Geneva, Switzerland, 2006.
7. ISO 14044:2006. Environmental Management - Life Cycle Assessment - Requirements and Guidelines. International Organization for Standardization: Geneva, Switzerland, 2006.