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Participatory modelling of the water-energy-food nexus: A case study of a cassava processing hub in oyo state, Nigeria

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Abstract

Cassava production plays a crucial role in providing food and income for smallholder farmers, and raw materials for agro-processors in Nigeria. A cassava processing hub serves as a shared facility for agro-processors to aggregate and process cassava, using common infrastructure to ensure processing efficiency, increase market access, and improve their livelihoods. However, interlinked pressures on water, energy, waste management, and local environmental systems are increasingly constraining their expansion. This study examines the dynamics that impact the sustainable growth of a cassava processing hub in Oyo State, Nigeria. The processors collectively manage approximately 6–9 tons of cassava per processing cycle, reflecting a small- to medium-scale processing operation. The hub is established on a shared land area of 4,180.64m^2, enabling access to pay-as-you-use equipment and infrastructure that would otherwise be too costly for smaller-scale processors. Hence, a participatory system dynamics modelling approach was employed using qualitative insights from Focus Group Discussions (FGDs) with cassava processors. These insights were used to develop a System Dynamics Model (SDM) in Stella Architect, by applying the Limits to Growth system archetype, represented through Causal Loop Diagrams (CLDs). The CLDs illustrate how initial expansion in processing capacity is constrained by resource dependencies and negative environmental feedback. The SDM reveals how feedback loops, time delays, and non-linear relationships link water use, energy demand, processing capacity, and waste discharge. Results indicate that while processors pursue expansion through a reinforcing production loop, this growth is systematically constrained by five balancing loops: environmental impact (B1), water resource dependency (B2), energy resource dependency (B3), waste management limitations (B4), and escalating operational costs (B5). By explicitly identifying these structural constraints and their interactions, the study advances system-level understanding of sustainability challenges in cassava processing hubs. The study concludes that unlocking resilient, inclusive, and sustainable growth requires coordinated interventions, including communal wastewater infrastructure, resource-efficient technologies, strengthened governance among processors, and improved access to training and knowledge through a combination of processors' collective efforts and support from Oyo State government extension services and development agencies. These insights position participatory system dynamics modelling as a practical decision-support tool for guiding sustainable agro-processing development.

Keywords: Cassava, limits to growth, participatory modelling, wastewater

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