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Leverage Points for Decelerating Wetland Degradation: A Case Study of the Wetland Agricultural System in Uganda

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Abstract: Indiscriminate expansion of agricultural activities into wetlands affects the sustainability of wetland-dependent livelihoods. Systems research is an important tool for identifying and dealing with the underlying drivers of wetland degradation; however, there is limited research employing system tools in Sub-Saharan Africa. This research employed causal loop diagrams and system archetypes to characterize common wetland resource systems in Sub-Saharan Africa, using the wetland agricultural system of Uganda as a case study. Mental models of wetland users were indirectly elicited by interviewing 66 wetland users. Causal loop diagrams were generated to illustrate the multiple, interdependent feedback linkages within the system. The case study wetland is mainly used for farming (40%), vegetation harvesting (26%), and fishing (24%), while other activities like hunting and grazing are carried out by 10% of wetland users. A reinforcing feedback loop was dominant, illustrating how initial encroachment on the wetland to meet livelihood needs can accelerate further encroachment. Based on the dominant loop and current interventions, we characterized the system using three archetypes: tragedy of the commons, shifting the burden, and fixes that fail. A two-pronged approach was proposed, where solutions for decelerating wetland degradation, like restoration activities, can be implemented in the short term while planning long-term measures that take into account the need for alternative livelihoods for wetland-dependent communities and targeting a paradigm shift through continuous sensitization of stakeholders on the benefits of sustainable wetland management.

Keywords: sustainable wetland management; system thinking; causal loop diagrams; archetype analysis

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1. Introduction

Agriculture is the leading source of livelihood for rural communities in developing nations [1–3]. For many of these countries, wetlands are vital for meeting food security needs [4]. However, the growing pressure from agricultural expansion has led to over-exploitation of wetlands and their subsequent degradation [5–11]. This has impacted their ability to provide provisioning services like fresh water for domestic use, crop irrigation, fisheries, livestock watering, as well as vegetation for crafts and roofing, among others [8,12–14]. In addition, wetland drainage has negative impacts on groundwater levels and soil moisture, which affects water availability and agricultural sustainability in the long run [15,16].

Although wetland ecosystem services have become better known in recent years, implementing sustainable wetland management is problematic. This is because the ecosystem services that benefit a wider society like purification of water or mitigation of floods may not be economically beneficial to individuals adjacent to wetlands, compared to drainage, which provides immediate benefits, for example, land for agricultural expansion [17]. Therefore, wetland management, including for agricultural uses, should aim to maintain a balance between the provisioning and regulatory functions of wetlands.

In Sub-Saharan Africa, wetlands have been severely degraded due to encroachment for industrial, residential, and agricultural expansions [18,19]. Rural wetlands are particularly under pressure to meet the food security needs of small-scale farmers [18]. Due to their contribution to the agriculture sector, for the purpose of this study, we define rural wetlands as wetland agricultural systems. The wetlands are used for farming while at the same time providing other services important for rural livelihoods.

In Uganda, 2.5% of wetland cover was lost between 1994 and 2017 [19]. Despite multiple actions to evict encroachers combined with community awareness-raising campaigns throughout the country, wetland encroachment continues unabated [18,19]. This partly indicates that the management of wetland agricultural systems is a complex and dynamic process with many actors of varying values and interests, as well as multiple feedback loops within the systems. The complexity requires that wetland managers and other stakeholders take a systems approach, not basing only on linear cause–effect relationships but considering nonlinearities, including delays in physical and information flows within the systems [20,21]. Managers should not focus on individual system events like an incident of encroachment at a given time stamp but rather on the behavior of the system over time as well as the system structure [22].

While there is a growing global trend in employing system tools in agricultural, water, and energy systems, research in this area is limited in Sub-Saharan Africa [23]. The few available studies are concentrated in West Africa [24–26]. Given the high natural resource degradation prevalent in the East African region [27,28], systems research is an important tool for identifying and dealing with the underlying drivers of degradation.

Systems thinking is an essential approach for enhanced understanding of the underlying structure of a system through characterizing feedback processes within it [29,30]. The approach facilitates making inferences about system behavior, as well as identification of areas within the system from which desired change can be achieved. In addition, it aids in anticipating potential unintended consequences of implementing a solution for a given problem [31–33]. This approach is particularly crucial in the context of effective natural resource management, where multifaceted and dynamic challenges necessitate consideration of the broader environment, interconnections, feedback mechanisms, and delays in feedback among different components of the system [23,32,34,35].

System dynamics offers a range of modeling methods that facilitate the analysis of dynamic systems [36]. It incorporates both qualitative and quantitative tools, with the former employed to gain insights into system structure and the latter facilitating quantitative simulation of changes in system variables. Qualitative system dynamics tools include causal loop diagrams, stock and flow diagrams, reference modes, and system archetypes, among others [20,23,32,36,37]. Causal loop diagrams and stock and flow diagrams are instrumental in illustrating the feedback structure of complex systems [31], while reference modes illustrate changes in variables over time. On the other hand, archetype analysis focuses on assessing recurring characteristics shared across multiple cases [36]. Thus, systems can be grouped into characteristic archetypes based on their structure, feedback loops, and similar behavioral patterns. These archetypes contribute to the characterization of system structure, offering insights into foreseeing the long-term behavior of a system [23,32,38].

Prominent archetypes within system dynamics have been identified and categorized based on the prevalent feedback loops, which may be reinforcing, balancing, or a combination of both [32,39]. These include tragedy of the commons, fixes that fail, success to the successful, shifting the burden, and drifting goals, among others [31]. Each archetype represents a distinct systemic pattern with specific feedback dynamics. In the system dynamics literature, various general solutions for modifying system structure in the context of each archetype have been proposed. It is crucial to note that these solutions should be tailored to local contexts, considering the specific intricacies of each system [31,32].

This research employed qualitative system dynamics tools, specifically causal loop diagrams and system archetypes, to illustrate their usefulness as diagnostic instruments to characterize common resource systems like wetlands in Sub-Saharan Africa. The specific objectives were to (i) characterize the feedback structure within the wetland agricultural system, (ii) identify the dominant archetypes driving the system, and (iii) identify areas within the system with the potential to influence desired changes. We used a case study of a wetland agricultural system in rural Uganda, which provides multiple services to communities and is heavily relied upon for agricultural production, leading to widespread degradation and a recurrent cycle of evictions and re-encroachment [18,19].

2. Materials and Methods

2.1. Study Area

This study was carried out on the Naigombwa wetland agricultural system, which is located in Eastern Uganda. It covers an area of approximately 177 km^2, crossing through the districts of Bugiri, Bugweri, Iganga, and Kaliro [40]. Its catchment area is approximately 1700 km^2, extending to the districts of Mayuge and Namutumba (Figure 1). Naigombwa wetland is a permanent swamp with *Cyperus papyrus* (commonly known as papyrus), as the dominant vegetation, which floats on buoyant root mats [41]. The wetland is fed by the Naigombwa River, which eventually discharges into the Mpologoma wetland and finally into Lake Kyoga. Upstream sections of the wetland in Bugiri have been completely converted into small-scale rice paddies, and segments of the wetland in Bugweri are used for commercial rice farming. The midstream and downstream sections are moderately degraded, with patches of rice paddies at wetland edges and papyrus vegetation in the center. Other activities in the wetland include fishing (mud fish), papyrus harvesting, grazing, and commercial sugar cane farming.

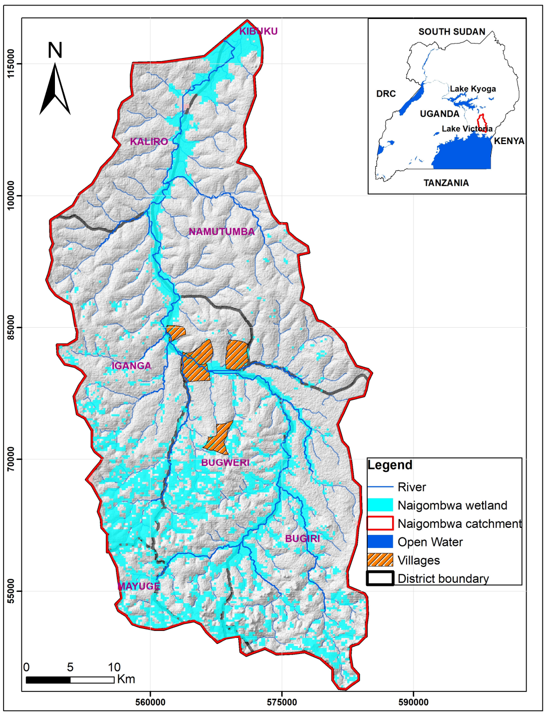


Figure 1. Map showing location of Naigombwa wetland and villages where the interviews were carried out.

The population size of the Naigombwa catchment is approximately 1,865,800, and over 80% of these people depend on subsistence farming for their livelihoods [42,43]. The predominant crops in the catchment area include maize, beans, cassava, groundnuts, millet, and sweet potatoes. The soils in the area are largely shallow sandy loams with an average depth of 30 m and overlying bedrock. The average annual rainfall is 1300 mm, characterized by two peak rainy seasons in March–May and September–November [41].

2.2. Data Collection

For the purpose of characterizing feedback loops within the wetland agricultural system, we used interviews as an indirect method of obtaining the internal mental perceptions of community members about how the wetland agricultural system works [44–48]. We used Naigombwa wetland in Eastern Uganda as a study site. Communities adjacent to the mid-stream section of the wetland were selected for the interviews, which were conducted in May 2022. The mid-stream section was selected because it has both degraded and intact wetland patches, which provided an opportunity to interview individuals benefiting from different wetland services other than agricultural activities. Five villages adjacent to the mid-stream section were purposively selected for the interviews to cover areas of the wetland that were degraded and those that were intact. The study population for the selected villages was all households adjacent to the wetland and using the wetland for livelihood activities like farming, fishing, and vegetation harvesting. For each household, the household head was interviewed. However, the most senior and knowledgeable family member was interviewed in situations where the household head was absent.

The interviews were conducted until a point of saturation was reached, where there was no new information obtained from additional interviews [26,49]. The interviewees were identified with the help of the local council chairpersons of the 5 villages prior to the interviews since they knew which households used the wetland for livelihood activities. A local council is the lowest administrative unit in Uganda. A total of 66 people were interviewed, 61% of whom were male and 39% female. The interviewees included 32 farmers, 14 fishermen, and 20 vegetation harvesters. The number of people interviewed is consistent with previous studies using the qualitative systems approach to characterize system structure [26,50–52].

The interview questions explored themes about the drivers of wetland degradation within the wetland agricultural system, impacts of degradation, feedback links with crop yield and other livelihood activities, as well as possible solutions for sustainable wetland use. In order to establish a cause–effect relationship as well as feedback between variables, questions to the wetland users were of the following form: (i) the activities they carry out in the wetland, (ii) what motivates them to use the wetland for activities mentioned, (iii) what changes they have observed occurring in the wetland, (iv) what they think is causing these changes, (v) how the activities they carry out within the wetland have changed over time, (vi) what is the reason for the change in activities, and (vii) measures they would take to ensure sustainable use of the wetland, among others.

2.3. Data Analysis

The main variables in the wetland agricultural system were identified by cataloging the drivers of wetland encroachment and the impacts of wetland encroachment as characterized by wetland users during the interviews (Table 1).

Using Vensim software (Vensim PLE Plus 9.1.1), the cause–effect relationship between drivers of encroachment, impacts of degradation, and feedback between them were illustrated by establishing linkages (relationships) between variables using arrow connections. An arrow indicates the direction of the relationship between variables [33]. For example, if interviewees stated that the removal of wetland vegetation impacted the income of vegetation harvesters, the arrow is drawn with a direction from "vegetation removal" to "income from vegetation harvesting". Positive (+) signs are used for each arrow to represent variables changing in the same direction, i.e., an increase in vegetation removal leads to an increase in income of vegetation harvesters. On the other hand, negative (−) signs are used for variables changing in opposite directions, i.e., an increase in drainage leads to a reduction in water level. Return arrows from "impact of degradation" variables to "drivers of degradation" variables are used to indicate where there was feedback within the system. The feedback arrows are based on interviewees' answers, which showed that the impacts of degradation, in turn, influenced the kind of activities carried out within the wetland system. For example, wetland drainage reduces water level and soil moisture over time, and the reduced soil moisture affects crop yield, which causes farmers to drain other parts of the wetland. Therefore, adding feedback arrows created a closed loop/cycle for any set of variables with a cause–effect relationship. Each closed loop was labeled with short phrases to describe the main theme of the loop, for example, "agricultural expansion into wetlands", "food security and economic security feedback loops", and others. In addition, positive (+) and negative (−) signs are used to define the polarity for each closed loop, where plus (+) represents a reinforcing loop, and negative (−) represents a balancing loop. A reinforcing loop is a cycle in which an increase/decrease in any variable propagates through the loop and causes a further increase/decrease in the initial variable of interest, while a balancing loop is a cycle in which a change in any variable propagates through the loop and causes a reduction in the initial change of the variable of interest [33].

Table 1. Variables in the wetland agricultural system identified through interviews.

No	Drivers of Wetland Degradation	Activities Carried out in Wetland	Common Practices	Impacts of Wetland Degradation
1	Food needs - Expansion of agricultural activities into wetland because wetland has more moisture	1. Crop farming 2. Livestock grazing 3. Livestock watering 4. Withdrawal of water for irrigation	Creating drainage channels Removal of natural wetland vegetation (papyrus)	- Lower water table (note: intact wetland has up to 2 m of water in wet season, which makes it difficult to carry out cultivation) - Reduced water storage - Reduced soil moisture - Reduced fish caught - Reduction in game - Reduced water quality
2	Income needs	1. Fishing 2. Vegetation harvesting 3. Hunting		
3	Land tenure - perception that wetland is free to use	1. Withdrawal of water for domestic use 2. Baptism for the Seventh Day Adventists 3. Harvesting of medicinal herbs		

The causal loop diagrams generated were presented to stakeholders at a workshop with 30 participants, including small-scale and commercial farmer representatives, environmental officers, agriculture officers, academia, the media, and the private sector, with the aim of corroborating the information generated from wetland users. In the workshop, a series of presentations were made about system dynamics and system thinking; generation of causal loop diagrams; the research problem; and the data collection procedure. The participants were divided into 4 groups, and each group was tasked to generate causal loop diagrams, which were later presented and discussed in a plenary session (Figure 2). The causal loop diagrams were updated to include input from the workshop participants. A list of workshop participants is provided in Appendix A.

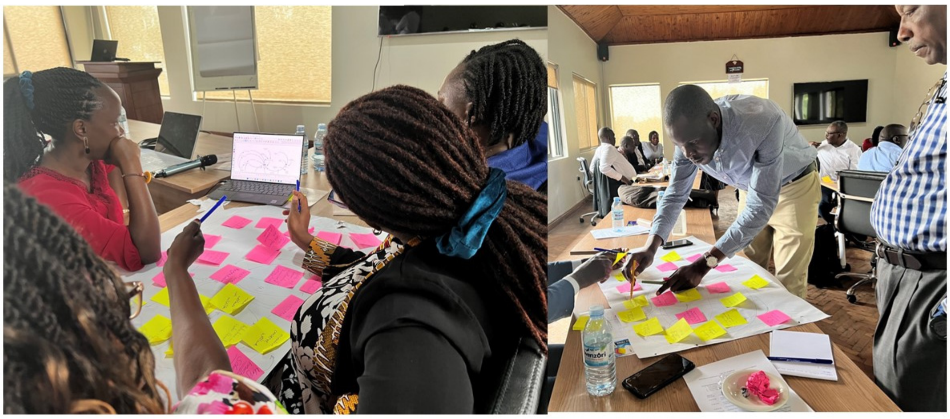


Figure 2. Workshop participants generating causal loop diagrams.

The final updated causal loop diagrams were used for general archetype characterization. Archetypes are defined as "common system structures that produce characteristic patterns of behavior" [31,39]. They have been applied in previous research as diagnostic tools to identify behavioral patterns existing in any system of interest [53]. We used a checklist to compare characteristics of existing archetypes in the literature [31,39,53] to the characteristics of the wetland agricultural system (Table 2), following methods used by other researchers [54–57]. We used diagnostic questions/statements in the check list to identify archetypes whose characteristics had a more than 70% match with the observed behavior of the wetland agricultural system, as depicted in the causal loop diagrams (information from interviews and stakeholder workshops). The chosen archetypes were "tragedy of the commons", "fixes that fail", and "shifting the burden" [31,39]. A more detailed description of the chosen archetypes is provided in Appendix B.

Table 2. Checklist matching characteristics of common system archetypes to the wetland agricultural system of Uganda.

No	System Archetype	Description	Diagnostic Questions/Statements	True or False
1	Fixes that fail	Refers to situations where a problem symptom presents, a solution is applied to fix that symptom but after the solution is applied, unintended consequences occur, which make the original symptom worse	- Is wetland encroachment a symptomatic problem?	Yes
			- Is there an underlying cause of wetland encroachment?	Yes
			- Are current solutions causing unintended consequences	Yes
2	Tragedy of the commons	This archetype occurs where multiple people benefit from the use of a common resource. Each individual tries to maximize their benefits. This leads to over exploitation. Over exploitation continues until the common resource exceeds its capacity, which affects its ability to provide goods/services	- Are there multiple people dependent on the wetland agricultural system	Yes
			- Is the resource over exploited	Yes
			- Has the capacity of the system to provide ecosystem services been affected?	Yes

Table 2. *Cont.*

No	System Archetype	Description	Diagnostic Questions/Statements	True or False
3	Shifting the burden	In this archetype, the focus is put on solving the problem symptom rather than concentrating on the underlying problem. This is because it is easier to implement the symptomatic problem rather than longer term solution in terms of time and financial investment	- Are short-term solutions implemented?	Yes
			- Does the short-term solution relieve the problem symptom?	Yes
			- Does the problem symptom re-occur?	Yes
			- Are long-term solutions implemented?	Yes, not systematically. Only in some areas
4	Limits to growth	This archetype represents systems in which any exponential growth begins to slow down as the limits of that system are approached. Any efforts to increase growth produce diminishing returns	- Is there exponential growth crop productivity (past and present)?	No
5	Success to the successful	Occurs in a situation where the initial success of a group/individual against another results in rewarding or investing more resources with the group/individual that had a better performance at the beginning. This creates a situation where the former continues to have a better performance due to more investments while the later continues to perform worse due to less investment	- Are there differences in performance of different wetland users?	The goals of different users are different (increasing food for substance versus increasing income)
			- Are wetland users rewarded based on their performance?	No
6	Escalation	This archetype describes a situation where two groups are competing in a system. The first group acts in a way that is perceived as a threat by the second group, leading the second group to retaliate. This leads to even more aggressive actions from the first group. The two groups become increasingly aggressive over time	- Is there competition between the different wetland users (vegetation harvesters, farmers, fishermen)?	No
			- Are commercial farmers and small-scale farmers in a cut-throat competition with each other?	No
7	Eroding/drifting goals	Refers to a situation where a gap between reality and a given goal can be closed by either lowering the goal or taking corrective action. The option of lowering the goal is usually taken because it immediately closes the gap as opposed to taking corrective action, which takes a longer time to achieve any results. This leads to fluctuations in performance within a system, and over time the goal is reduced lower and lower to ensure a small gap between reality and the goal	- Has the goal of attaining sustainable wetland management been diminished over the years?	No
			- Is there is any corrective action to address wetland degradation?	Yes
8	Growth and underinvestment	This refers to situations where limits to growth can be overcome through capacity investments. However, if a given system is pushed beyond its limit for a long time, it responds by reducing its performance, which then leads to less investment over time.	- Are wetland users increasing investment in capacity?	No

Table 2. *Cont.*

No	System Archetype	Description	Diagnostic Questions/Statements	True or False
9	Accidental adversaries	This refers to a situation where two groups are initially working together towards achieving shared goals, by maximizing their strengths and minimizing their weaknesses. However, one group carries out an action that is perceived as a threat, which causes the second group to respond in a retaliatory manner.	- Are the wetland users working together towards a common goal?	No

Leverage points for sustainable management of wetland agricultural system were identified based on general archetype-aligned solutions in the literature [31,32] within the social–political context of Uganda. We define leverage points as points within the wetland agricultural system with the highest potential to influence all other variables within the system, thus leading to a change in behavior of the system [31,33,53,58]. For example, the authors of [31] proposed the following generic solutions for the three identified archetypes, respectively: (i) education combined with regulation through permits, taxes, or incentives; (ii) policies that cater for the welfare of the entire system in an effort to balance goals of different stakeholders; and (iii) addressing underlying problems through long-term planning. The methods of data collection and analysis are summarized in the methods flow chart, Figure 3.

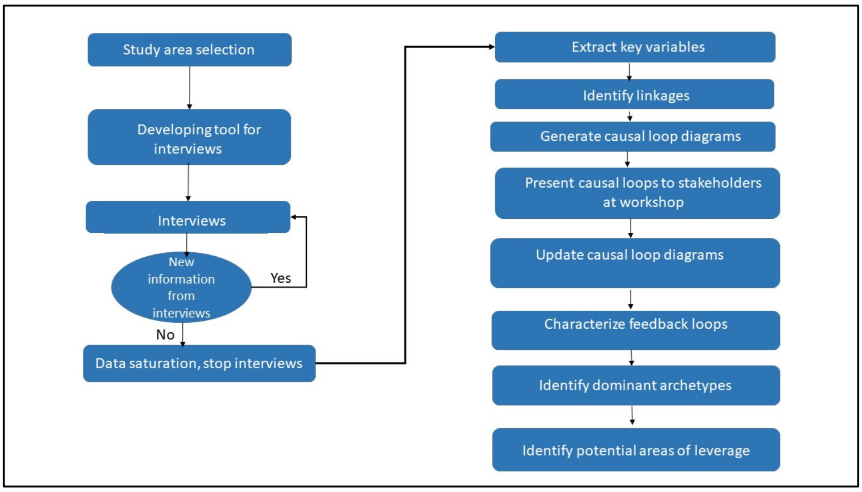


Figure 3. Methods flow chart.

3. Results

3.1. Dominant Feedback Loops and Characteristic Archetypes

The causal loop diagrams illustrated several feedback loops in the wetland agricultural system, which are presented in the following sub-sections. Each feedback loop is compared to an existing archetype structure to identify characteristic archetypes of the wetland agricultural system.

3.1.1. Food and Economic Security Feedback Loops

Farming is the dominant activity in the wetland, and interviewees asserted that food and income needs are the main reasons of using the wetland. Most of the interviewees (64%) depend on the wetland for household food needs through farming (40%) and fishing (24%). A total of 26% of interviewees get their income from wetland activities like vegetation harvesting, and 10% used the wetland for other uses like hunting, grazing, and as a source of medicine, among others (Figure 4).

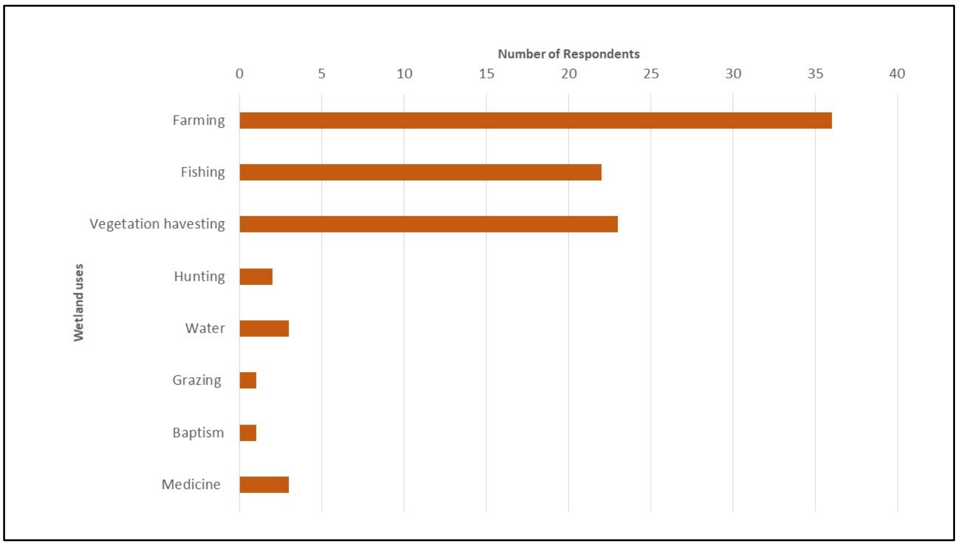
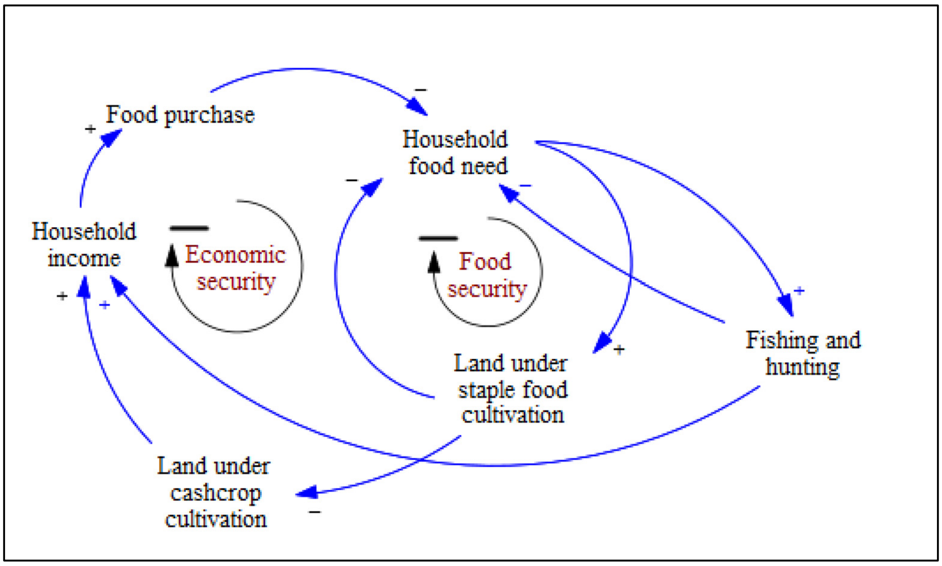


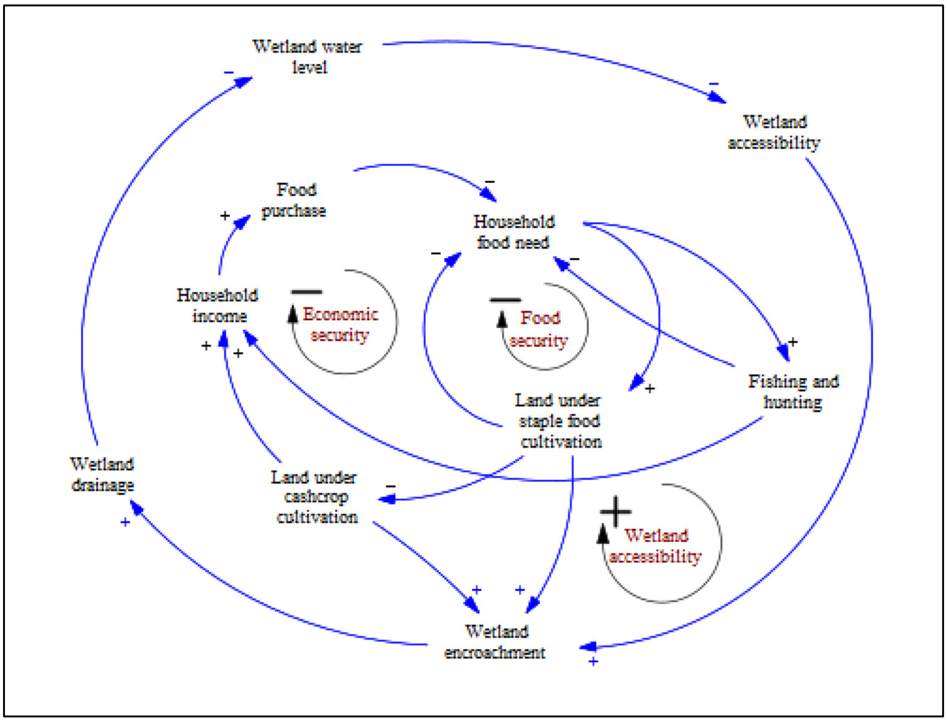
Figure 4. Uses of Naigombwa wetland by households.

The relationships between meeting food/income needs and the use of wetlands are represented by the food security and economic security feedback loops (Figure 5a), which are both balancing loops. This means that once wetland users meet their food and income needs then this reduces household food needs. However, meeting these needs leads to encroachment on the wetland through vegetation removal and drainage. Drainage lowers the wetland water level, making the central part of the wetland more accessible for encroachment, as illustrated by the reinforcing loop "wetland accessibility" (Figure 5b).



(**a**)

Figure 5. *Cont.*



(**b**)

Figure 5. (**a**) The food and economic security feedback loops. (**b**) The wetland accessibility loop.

These loops illustrate how the households depend on wetland resources to meet livelihood needs. However as more household needs are met there is more wetland drainage, and it becomes easier for the remaining wetland to be encroached upon due to reducing water levels, which creates a reinforcing loop of wetland degradation. The reinforcing loop is influenced by the fact that each individual tries to increase the benefit that they get from using the wetland. This system behavior is consistent with the 'tragedy of the commons' system archetype.

3.1.2. Impacts on Wetland Goods and Services Feedback Loops

Agricultural expansion into wetlands has short-term and long-term impacts. Short-term impacts include loss of wetland flora and fauna, which affects income generation for individuals who are solely dependent on hunting, fishing, and vegetation harvesting. A reduced income affects their ability to supplement their household food needs. Furthermore, removal of flora, e.g., papyrus, reduces the water purification function of the wetland, which makes water unfit for domestic and irrigation use. On the other hand, long-term impacts included declining crop yield, which was reported by 80% of the interviewees.

These feedback relationships are illustrated in Figure 6 using the "impact on wetland goods", "impact on wetland services" loops for the short-term impacts, and long-term impacts, respectively. These are all reinforcing loops that are characteristic of the "tragedy of the commons" system archetype.

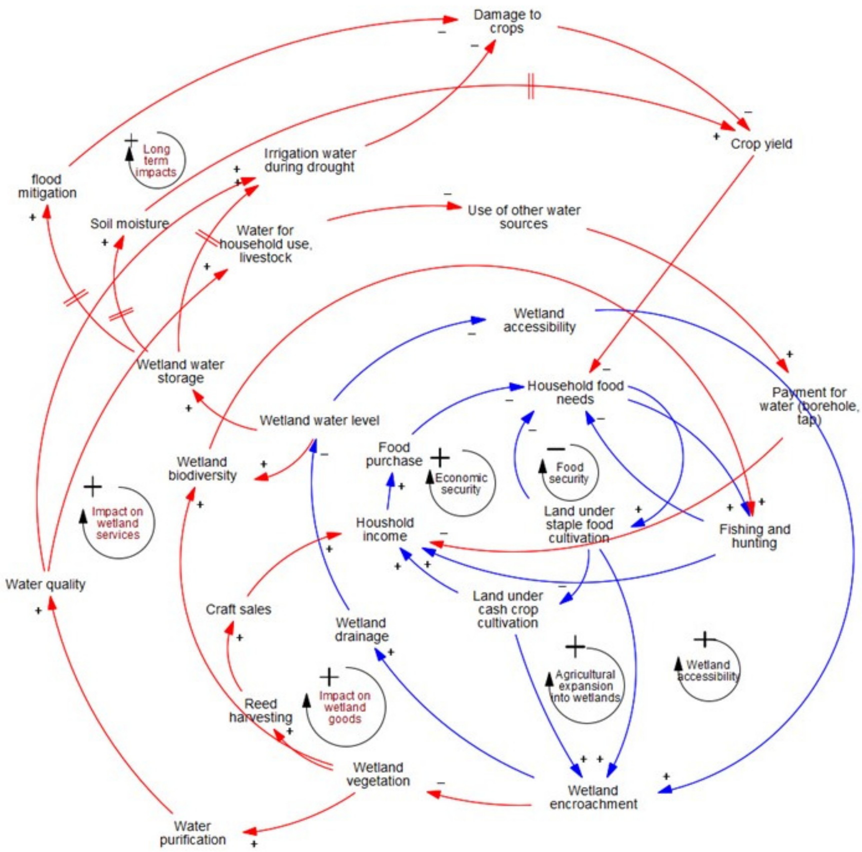


Figure 6. Short and long-term impacts of degradation on wetland goods and services. Blue arrows show the drivers of wetland degradation, while red arrows show the impacts of degradation.

3.1.3. Response to Wetland Degradation Feedback Loop

Interviewees indicated that the government responds to wetland degradation by effecting evictions from the wetland. Eviction of farmers from wetlands is characteristic of the "shifting the burden" archetype because the focus is majorly on the symptomatic problem rather than the underlying drivers of wetland encroachment, which are poverty and lack of alternative livelihoods that ultimately force farmers back into the wetlands. A lack of livelihoods results in re-encroachment on wetlands, and this is characteristic of the "fixes that fail" archetype, where interventions within a system lead to unintended consequences that disrupt any positive gains made in achieving the desired behavior of a system.

3.2. Potential Measures for Mitigating Wetland Degradation

Wetland users recommended a number of measures for mitigating wetland degradation. These included wetland edge farming (26%), regulating cultivation (23%), avoiding vegetation burning (20%), avoiding use of pesticides and herbicides (18%), and allowing for fallowing (13%), among others (Figure 7).

The proposed measures show that wetland users prefer measures that allow them to continue using the wetlands for their livelihoods. This demonstrates that promoting wise use of wetlands (e.g., wetland edge farming, which is allowed by law) could be one of the potential areas to leverage for sustainable management of the wetland agricultural system.

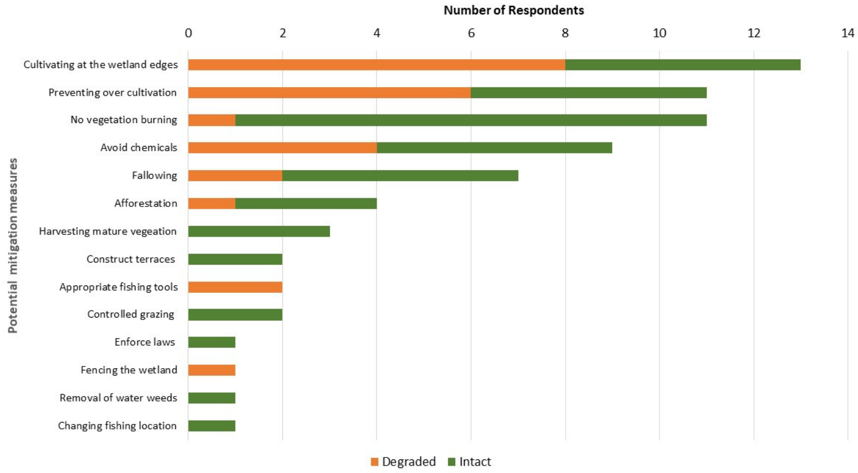


Figure 7. Potential measures for mitigating wetland degradation, as proposed by wetland users. Orange and green colors show measures proposed by households living close to degraded and intact wetland sections, respectively.

4. Discussion

In this section, we discuss the wetland agricultural system based on the three system archetypes that were selected after archetype analysis. The relevant archetypes include (i) tragedy of the commons, (ii) shifting the burden, and (iii) fixes that fail. The discussion is presented in view of potential leverage points for effective wetland management within the socio-political context of Uganda.

4.1. Tragedy of the Commons

Characterizing the wetland agricultural system through the "tragedy of the commons" archetype shows that the individual actions of different stakeholders using the wetland for varying needs lead to the degradation of the wetland, affecting its capacity to provide ecosystem services as a whole [37]. This affects stakeholders in terms of reduced crop productivity, increased flood incidents, reduced vegetation for harvesting, and declining fish caught, among others, as illustrated using the "impacts on ecosystem services" loop in Figure 6. The "tragedy of the commons" structure has been reported to be characterized by a weak feedback link between individuals' decisions to use the common resource and the deteriorating state of the resource [31]. This is because each individual benefits directly from using the wetland, but the costs of wetland degradation are shared by everyone. The weak feedback eventually leads to resource overuse, which affects the ability of the resource to regenerate over time [31,37]. One way to deal with the "tragedy of the commons" structure is to devise means to strengthen the communication link between each individual's actions and the impacts of their actions [31], for example, by instituting measures where users of the common resource are able to comprehend the long-term consequences of their negative actions. This can be through introducing licenses and/or fines to enforce the wise use of a common resource.

In Uganda, such measures do exist and are provided for in The National Environment (Wetlands, River Banks and Lake Shores Management) Regulations, for Uganda, No. 3/2000, where the use of the wetland requires one to submit an application and obtain a permit from the Executive Director of the National Environmental Management Authority (NEMA). However, there are several factors that weaken the effectiveness of this intervention. The first is that the requirement for a permit does not apply to vegetation harvesting or agricultural activities that use less than 25% of the total wetland area. The implication of this is that multiple smallholder farmers can use up a cumulative wetland area exceeding the 25% limit without the need to obtain a permit for wetland use. This loophole buffers individuals from the responsibility for the long-term impacts of their actions. The second limitation is that implementation of the regulations is hindered because local wetland users may not be aware of proper procedures for attaining resource use permits. Moreover, there is only one central issuing authority located in the capital city, Kampala. A third factor is that implementation is prone to political interference, where the law is enforced strictly for the poor but not the same way for the rich or those with political backers. Poor implementation of the law then leads to frequent stakeholder conflict, distrust of government, and a loss of gains made towards sustainable wetland management, as has been observed elsewhere [59,60]. The final aspect that makes instituting wetland licenses a weak leverage is the fact its implementation does not change the underlying system structure [31,58], but the original problem can persist if other feedback like high population growth rate, as well as socio-political factors that influence the decision making of public servants and political leaders are ignored [58].

Although introducing licenses is a weak leverage, its effectiveness can be improved with the establishment of local environmental committees, which can put in place by-laws and enforce penalties for those that fail to follow agreed actions. Areas without local environmental committees should be encouraged to form them since this is provided for under the National Environmental Act, no 5 of 2019. On the other hand, for areas where local environment committees already exist, members should be trained to come up with context-specific management strategies so that they are empowered to develop appropriate and acceptable incentives and penalties to promote the sustainable use of wetland agricultural systems in their jurisdictions.

4.2. Shifting the Burden

Encroachment of wetlands for agricultural activities is due to household aspirations to meet food and economic needs, which leads to the symptomatic problem of wetland degradation. It is proposed in the literature that the best way to deal with the "shifting the burden" archetype is to implement short-term solutions while buying time to implement longer-term solutions, which require investment of a large amount of resources and time [37]. In Uganda, the problem of wetland encroachment has largely been addressed by focusing on the symptomatic problem; hence, interventions usually aim at evicting people from wetlands and restoration of degraded wetland areas. This gives a temporary positive effect of success, but eventually, the wetland is encroached upon again. Since the causal loop for the wetland agricultural system illustrates that there is a reinforcing loop of degradation driven by individuals' livelihood needs, a more fundamental solution would be to focus on the underlying causes, which include poverty and lack of alternative livelihoods. Addressing these underlying issues requires intentional long-term planning on the side of the government to ensure that these drivers of degradation are dealt with systematically.

It could be argued that there are no resources to cater to alternative livelihoods of all resource-dependent people, especially for developing nations like Uganda. However, in Uganda's case, there have been a number of programs aimed at improving household incomes, like the "Poverty Eradication Action Plan (PEAP)" [61] and the "Parish Development Model (PDM)" [62]. Such programs offer an opportunity to link government-led efforts to improve livelihoods with sustainable natural resource use. For example, by combining planned activities of the PDM like agricultural extension services, business management training, and processing/marketing of agricultural products with training on wetland edge best practices and value addition for wetland-derived products. Another way to leverage existing government programs is building on programs like the National Development Program NDPIII [63], which has as one of its objectives the promotion of intensive rather than extensive agriculture. Unfortunately, such programs are usually implemented without the full participation of all stakeholders, which leads to overlooking synergies and tradeoffs with the wetland sector.

All is not lost, however, because, in recent years, the Ugandan Government has begun wetland restoration programs that are tagged with alternative livelihood opportunities. These programs are normally implemented in wetland catchments that are deemed severely degraded and/or of national or regional importance [64]. However, it would be better if these solutions were systematically implemented together with restoration programs throughout the country instead of targeting only a few areas. In short, all catchments should be considered as target areas for alternative livelihood programs in the long run, even as the short-term solutions of eviction and restoration are being implemented. Although this two-pronged approach is a stronger leverage than instituting licenses proposed above, it is still limited by the large financial investment required as well as the need for cross-sectoral collaboration. The latter can best be achieved if all stakeholders have a similar understanding of the system structure so that they can together aim for the long term and more effective way of managing common resource systems [37].

4.3. Fixes That Fail

Interventions to reduce wetland encroachment lead to unintended consequences like distrust and hostility between wetland users and enforcement agencies, which is fueled by the loss of livelihood of the affected communities. This leads to disregard for government education programs on wetland use and subsequent re-encroachment and an increase in the rate of degradation. To address a "fixes that fail" scenario, acknowledging that certain conventional solutions may not be as effective as expected and deliberately planning for longer-term solutions has been suggested [37,39]. For the Ugandan case, there should be a deliberate effort to standardize penalties and incentives for blatant degradation and wise use of wetlands, respectively, irrespective of social and/or political class, in order to moderate unintended consequences of wetland restoration programs. For example, in July 2021, the Ugandan Government issued a directive banning agricultural activities in wetlands to ensure their sustainable management [65]. Whereas this is a step in the right direction, such orders usually target small-scale farmers with no regulation policies for commercial farmers or influential investors [66]. This creates an impression of unfairness to small-scale farmers who go on to resist evictions despite their understanding of wetland ecosystem services and the negative impacts of wetland degradation.

Another leverage proposed in the literature involves coming up with measures to slow down the reinforcing loop of degradation [31,58]. In Uganda's case, this could be actions that tackle other underlying causes of wetland degradation. For example, slowing down the population growth rate could give ample time for alternative livelihood programs to work without being overrun by a consistently high population. According to the authors of [58], it is also important to consider factors that influence decision making for public servants, legislators, and political leaders since their actions can lead to the success or failure of implementing any of the leverage points discussed here. That is the reason why both Refs. [31,58] stressed that the most powerful leverage is influencing peoples' perception of the system and how best to manage it.

Therefore, the most important point to intervene in the wetland agricultural system is to target peoples' paradigms about how the system should work, which can eventually change the system structure and thereby influence its emergent behavior [31,53,58]. The Ugandan Government has taken steps in the right direction, given the nationwide education campaigns about the wise use of wetlands that were run over two decades during the implementation of the National Wetlands Policy [18]. Such sensitization campaigns should continue while emphasizing the interconnectedness between agricultural activities and wetland systems. Since a paradigm shift is difficult to achieve in a short time, it is important to continue a two-pronged approach, where both short and long-term measures are implemented concurrently.

5. Conclusions

Having characterized the wetland agricultural system in Uganda using three different archetypes and discussing potential interventions, we conclude that there are a number of interventions that can be implemented for sustainable wetland management in Uganda. These include (i) instituting licenses for wetland use, (ii) systematically planning for and implementing both symptomatic and fundamental solutions, and (iii) targeting paradigm shifts through continued sensitization campaigns with all stakeholder groups. The interventions are listed in order from the weakest to the strongest leverage based on their ability to change the underlying system structure.

In order to make progress in wetland management in Uganda, none of the suggested interventions can work in isolation. Therefore, a two-pronged approach is proposed where short-term solutions should be implemented while planning long-term measures that take into account the need for alternative livelihoods for wetland-dependent communities, investing in incentives for slowing down population growth and targeting a paradigm shift through continuous sensitization of stakeholders on the benefits of sustainable wetland management including wetland users, managers, politicians, legislators, and the youth, among others.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors upon request.

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Appendix A. List of Workshop Participants

No	Designation/Institution	Number
1	Farmers	4
2	Technical Advisor- Water and Wetland Resources GIZ	1
3	Uganda National Association of Community and Occupational health (UNACOH)	1
4	Senior Agricultural Officer-Iganga District	1
5	District Natural Resource Officer-Iganga District	1
6	Department of Environmental Management Makerere university	4
7	Stewardship Institute of Environment and Natural Resources (SIENR)	3
8	Ministry of Water and Environment (MWE)	4

No	Designation/Institution	Number
9	Department of Agricultural productionMakerere University	2
10	Media, New vision	2
11	Makerere University, College of agricultural and Environmental Sciences (CAES)	1
12	Ministry of Agriculture, Animal Industry and Fisheries (MAAIF)	3
13	Environmental Officer-Iganga District	1
14	National Environment Management Authority (NEMA)	1
15	Professor-Department of Community sustainability, Michigan State University	1
Total Number of Participants		30

Appendix B. Description of Common System Archetypes

The following is a generic description of the system archetypes that were selected for this study, adapted from [37,39]. The illustrations use the symbols 'R' and 'B' to denote reinforcing and balancing loops, respectively, arrows indicate relationships between variables, while dotted lines represent delayed feedback.

Appendix B.1. Tragedy of the Commons

The "Tragedy of the commons" structure is common where multiple people benefit from the use of a common resource. Each individual tries to maximize their benefits from the resource, and the more profit they make, the more they exploit the resource, giving rise to reinforcing loops of over-exploitation. This continues until the common resource exceeds its capacity, which affects its ability to provide goods/services. The reduced capacity then creates a balancing loop that affects the net benefit of each resource user.

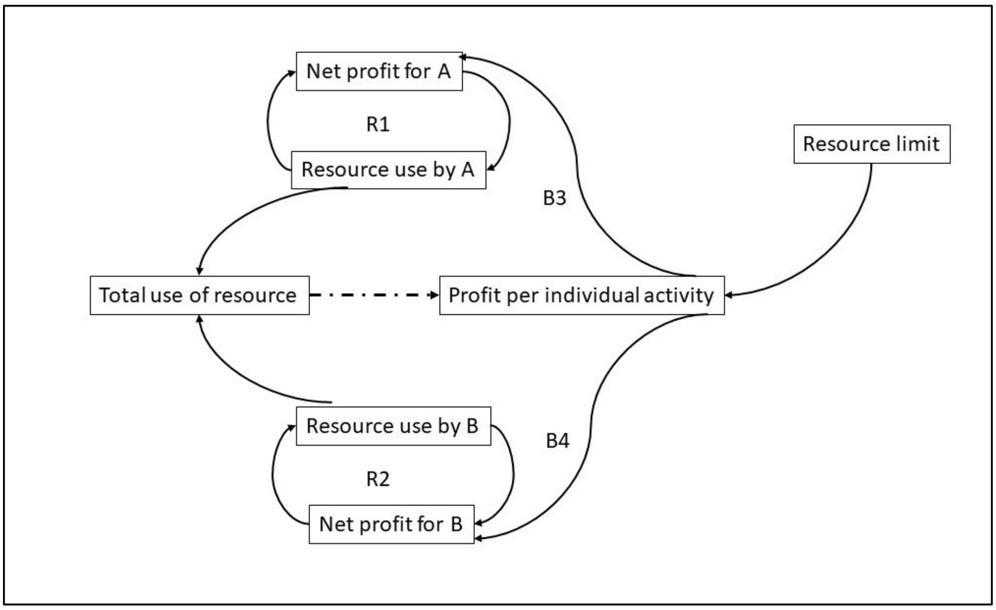

Figure A1. Tragedy of the commons. Arrows indicate relationships between variables, while dotted lines represent delayed feedback.

Appendix B.2. Fixes That Fail

The "fixes that fail" archetype occurs in situations where a solution is applied to solve a problem, but after some time there occurs an unintended consequence that may make the original problem worse.

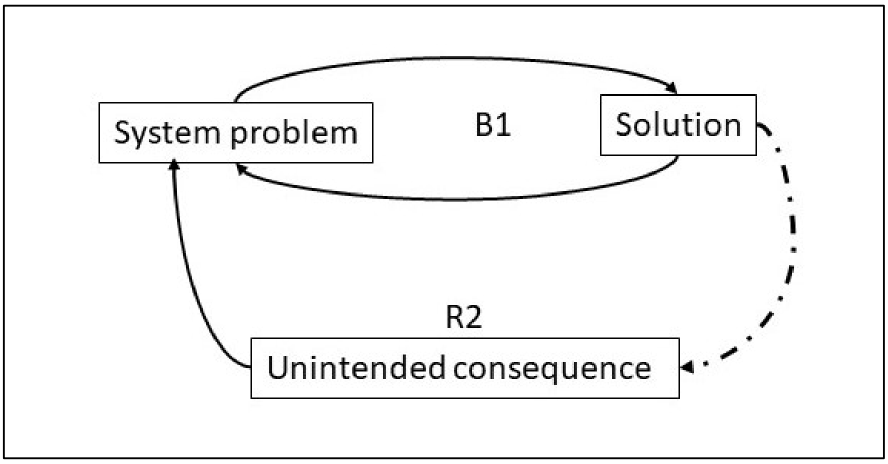

Figure A2. Fixes that fail. Arrows indicate relationships between variables, while dotted lines represent delayed feedback.

Appendix B.3. Shifting the Burden

The "shifting the burden" archetype arises when an underlying systemic issue gives rise to a symptomatic problem that is more visible and convenient to address in terms of time and cost. Consequently, the emphasis is placed on resolving the symptomatic problem rather than addressing the fundamental issue. Due to the persistent neglect of the underlying problem, the symptomatic problem recurs, necessitating continual application of the convenient solution. This iterative cycle diverts attention from identifying and rectifying the root cause. Furthermore, the symptomatic solution may introduce unintended consequences, impeding efforts to implement a more comprehensive and fundamental resolution for the underlying issue.

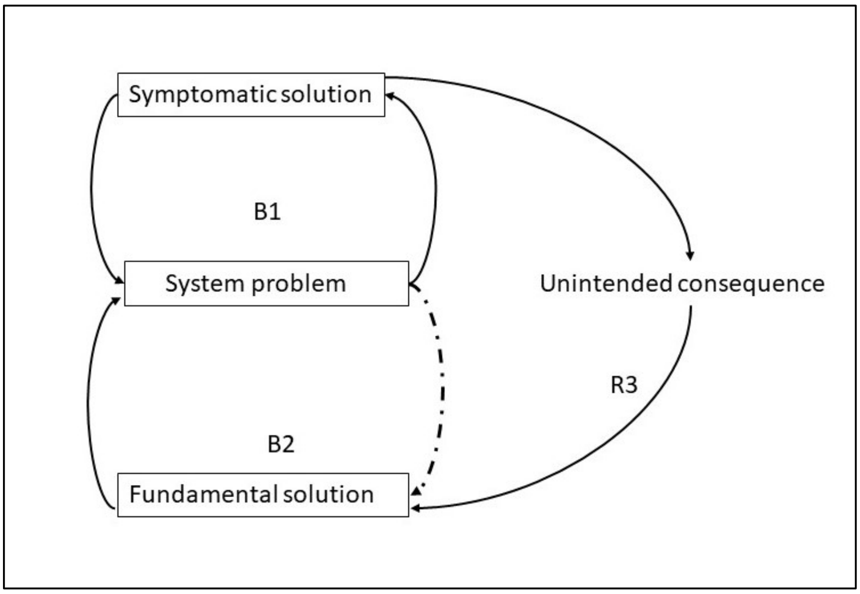

Figure A3. Shifting the burden. Arrows indicate relationships between variables, while dotted lines represent delayed feedback.

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