WATER AS A CIRCULAR RESOURCE IN REGENERATIVE AGRICULTURE: RISK GOVERNANCE AND CIRCULAR ECONOMY PRINCIPLES IN MOLDOVAN ECO-ENTERPRISES

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Abstract: *This study investigates the interplay between regenerative agriculture and circular economy principles through the lens of water resource governance in the Republic of Moldova. Water occupies a structurally central position in both paradigms: regenerative agriculture depends on the restoration and stewardship of water cycles, while the circular economy demands that water be treated not as a linear throughput input but as a continuously recirculated, quality-preserved resource. Drawing on a score-based risk assessment applied to each technological stage of the Chisinau municipal water supply system, from Dniester River intake through treatment, pumping, distribution, and operational management, the paper demonstrates that current water governance failures represent a systemic barrier to the uptake of regenerative and circular agricultural models in Moldova. The analysis identifies maximum-score risks (25/25) concentrated at the water intake stage, attributable to fluvial mismanagement, aging Soviet-era infrastructure, and the absence of a transboundary Dniester River Administration. The study integrates financial vulnerability assessment (Conan-Holder model) to quantify how water disruptions affect the balance-sheet resilience of eco-SMEs. Recommendations are grounded in circular economy design principles: closed water loops through aquaponics, constructed wetlands, and greywater reuse; regenerative soil-water management practices reducing irrigation demand; and institutional governance reforms enabling integrated water resource management consistent with the EU Water Framework Directive. The paper concludes that advancing the regenerative agriculture and circular economy nexus in Moldova is inseparable from resolving the country's water governance crisis.*

Keywords: *regenerative agriculture, circular economy, water risk management, Republic of Moldova, circular water loops, score-based risk assessment.*
JEL Classification: *Q25, M21, O13.*

1. Introduction

The twin paradigms of regenerative agriculture and the circular economy have emerged as central frameworks for rethinking sustainable development in the twenty-first century. Regenerative agriculture goes beyond mere sustainability: rather than simply maintaining existing natural capital, it seeks actively to restore degraded soils, revive biodiversity, rebuild hydrological cycles, and sequester carbon through land-use practices grounded in ecological systems thinking. The circular economy, meanwhile, challenges the linear extract-produce-discard model by advocating for closed resource loops, waste elimination, and the continuous recirculation of materials, energy, and water across economic systems.

Water sits at the intersection of both paradigms in a constitutive rather than merely instrumental sense. For regenerative agriculture, water cycle restoration through cover cropping, reduced tillage, soil organic matter enhancement, riparian buffering, and constructed wetlands is both a means and an end. For the circular economy, water is a prime example of a resource whose value is destroyed by one-way flows and whose utility is compounded by intelligent recirculation. Despite this conceptual convergence, the academic literature has rarely examined regenerative agriculture and circular economy principles together, and even more rarely through the concrete lens of water risk governance in transition economies.

The Republic of Moldova offers a revealing empirical context for this inquiry. As a small, agrarian, climate-vulnerable economy at the EU's eastern frontier, Moldova faces acute water governance challenges: a structurally fragile dependence on the Dniester River, a nascent but strategically significant eco-agricultural sector, pervasive informal agricultural employment, and an institutional framework for water risk management that falls well short of EU standards. At the same time, the country's National Development Strategy Moldova 2030, the Green Economy Package of 2018, and the National Strategy for Agriculture and Rural Development 2014-2020 all recognise the imperative to transition toward greener, more circular agricultural models.

This paper investigates the interplay between regenerative agriculture and circular economy principles specifically through the prism of water risk governance for eco-enterprises in Chisinau municipality. It applies a score-based risk assessment methodology, drawn from the WHO Water Safety Plan framework, to each stage of the municipal water supply chain operated by Apa-Canal Chisinau, and interprets the findings through regenerative and circular economy frameworks. The central argument is that the successful development of regenerative agriculture enterprises in Moldova requires not only circular water-use practices at the farm and firm level, but also systemic governance reforms that treat water as a shared circular resource at basin and national scale.

2. Litterature review

Gattinger et al. (2012) demonstrated through meta-analysis that organic and regenerative farming systems achieve significantly higher soil organic carbon stocks than conventional systems, with direct implications for water retention and drought resilience. Poeplau and Don (2015) quantified the carbon and water co-benefits of cover cropping, establishing that soil organic matter improvements translate directly into enhanced water infiltration and storage capacity. These soil-water relationships constitute the biophysical foundation of regenerative agriculture's contribution to circular water resource management.

On the circular economy side, Geissdoerfer et al. (2017) provide a comprehensive review of the circular economy concept, confirming that water is consistently identified as a priority circular resource across all major frameworks, with wastewater reuse, industrial symbiosis around water, and watershed-scale governance emerging as key implementation domains. The Ellen MacArthur Foundation (2015, 2021) reports emphasise the economic case for circular water management in the food system, estimating that transitioning global food production toward circular water practices could generate substantial economic value through input cost reductions, supply chain resilience improvements, and ecosystem service conservation. For Moldova, where agricultural water costs are near the lowest in the region, the economic argument is particularly powerful.

Rogers and Hall (2003) articulated the foundational framework for Integrated Water Resources Management, presupposing that water must be managed as an economic good with social and environmental dimensions simultaneously, a conception directly aligned with circular economy principles. Their work underpins the Water Safety Plan methodology deployed in this study. Boin et al. (2005) and the Romanian administrative risk management methodology documents provide the procedural grounding for the multi-stage risk matrix approach. The application of these methodologies to eco-agricultural enterprise water security represents a methodological contribution of this paper: score-based assessment had previously been applied primarily to public utility systems rather than to the enterprise risk landscape of eco-businesses.

Cano Rodriguez and Nunez Nickel (2006) confirmed that financial vulnerability to external shocks, including resource supply disruptions, is a systematic moderator of SME performance. For regenerative agriculture enterprises, which operate with longer time horizons and lower short-term returns due to transition costs and the multi-year nature of soil regeneration, this financial vulnerability is heightened and demands explicit risk management integration from business plan inception.

In this context, Moldova's National Development Strategy 2030, the Green Economy Package of 2018, and the National Strategy for Agriculture and Rural Development 2014-2020 collectively chart ambitions toward greener, more circular agricultural development. Oprea, Mutaf, and David (2014) document substantial gaps between policy ambitions and institutional implementation, particularly in disaster and climate risk management for agriculture. Santos (2019) confirms that adaptive responses remain fragmented and technology-focused rather than systemic, a pattern that circular economy and regenerative agriculture frameworks are specifically designed to transcend through their emphasis on systemic design over incremental improvement.

The scientific, economic, and governance foundations for integrating regenerative agriculture and circular water management are well established, yet their translation into enterprise-level risk practice, particularly for SMEs operating in institutionally fragile, climate-exposed transition economies such as Moldova, remains an unaddressed gap that this study directly seeks to fill.

3. Research Methodology

This study employs a mixed-methods research design integrating: (1) qualitative analysis of institutional and regulatory frameworks governing water management and eco-agricultural development in Moldova; (2) quantitative score-based risk assessment applied to the Chisinau municipal water supply chain; and (3) financial vulnerability analysis using the Conan-Holder (1978) model. All three analytical components are interpreted through the dual theoretical lens of regenerative agriculture and circular economy principles.

The risk assessment follows the WHO Water Safety Plan framework adapted in Moldova's National Guide for Water Safety Plans. For each technological stage of the water supply cycle, including intake, transmission aqueducts, water treatment, pumping stations, distribution networks, and operational management, each identified hazard is evaluated on probability of occurrence (scale 1-5) and severity of consequences (scale 1-5), yielding a composite initial risk score with a maximum of 25. After mapping existing control measures and monitoring protocols, a treated risk score is calculated. Hazards with treated scores above 10 are classified as residual high-priority risks requiring additional interventions framed within circular economy or regenerative agriculture logic.

Primary data are drawn from Apa-Canal Chisinau operational documentation, water quality laboratory records, and feasibility study reports. Secondary data include BNS statistical series, environmental monitoring reports from the Agency Apele Moldovei, and FAO agri-food price data for Eastern Europe. Geographical focus on Chisinau municipality is justified by its concentration of approximately 56% of national GDP, its dominant position in the eco-product retail market at 73% of national retail turnover, and its role as the primary node in Moldova's prospective regenerative agriculture supply chain.

4. Regenerative Agriculture as a Systemic Hydro-Ecological Approach

Regenerative agriculture is defined by its commitment to continuously improving the health of agricultural ecosystems rather than merely maintaining them. Its core practices, including no-till or reduced-till cultivation, diverse crop rotations, cover cropping, agroforestry, composting, and livestock integration, share a common mechanism: they rebuild soil organic matter, which in turn enhances the soil's capacity to absorb, hold, and slowly release water. Soils with high organic matter content can retain significantly more water per unit mass than depleted soils, dramatically reducing both irrigation demand and erosion-driven water quality degradation downstream.

This hydro-ecological function of regenerative soils directly addresses the water scarcity and water quality risks documented throughout this study. Farms that transition to regenerative practices reduce their exposure to municipal water supply interruptions because their reduced irrigation demand provides a buffer that conventional farms lack. They also generate positive externalities for downstream water users, including urban eco-enterprises, by reducing sedimentation, nitrate leaching, and pesticide contamination of river systems, which are precisely the contamination risks that currently inflate risk scores at the Dniester intake stage.

4.1. Circular Economy Principles Applied to Water

The circular economy, as systematised by the Ellen MacArthur Foundation and operationalised through the EU Circular Economy Action Plans, rests on three principles: eliminate waste and pollution; keep products and materials in use; and regenerate natural systems. All three principles apply directly to water management in the agricultural context. Water pollution elimination maps onto the contamination-risk reduction challenge throughout the supply chain. Keeping water in use translates into recirculation technologies including greywater reuse, rainwater harvesting, aquaponic closed loops, and constructed wetland effluent treatment. Regenerating natural systems corresponds precisely to the hydro-ecological functions of regenerative agriculture itself.

In circular economy terms, the current Moldovan water system is almost entirely linear: water is extracted from the Dniester, treated, used once, and discharged as wastewater with minimal recirculation. The municipal water consumption data for Chisinau, currently representing approximately 25% of historical Soviet-era peak volumes, reveals massive overcapacity in infrastructure built for a linear, high-throughput system. Transitioning to circular water flows would simultaneously reduce infrastructure stress, lower per-unit treatment costs, and increase enterprise resilience to supply disruptions.

The nexus between regenerative agriculture and the circular economy is most visible in three interaction zones. First, nutrient cycling: regenerative practices return organic matter to soils, creating biological nutrient loops that reduce dependence on synthetic fertilisers whose production is highly water-intensive and whose run-off drives water quality degradation. Second, water cycling: regenerative soils and agroforestry systems regulate the water cycle locally, reducing flash-flood peaks and maintaining base flows during low-water periods, outcomes directly relevant to the Dniester River's documented flow regulation challenges. Third, closed-system production: aquaponic and hydroponic systems represent the circular economy's inner loop applied to agriculture: virtually zero-waste, near-zero net-water-discharge production units whose economic viability has been demonstrated by Moldovan enterprises such as Salamer-Com LLC.

This theoretical convergence provides the analytical frame for interpreting the empirical findings that follow. Each risk identified in the water supply assessment can be reinterpreted as a failure point of the linear water system that circular economy and regenerative agriculture transitions are designed to overcome. Conversely, each circular or regenerative intervention generates co-benefits across multiple risk dimensions simultaneously, embodying the systemic logic that distinguishes these paradigms from incremental technical fixes.

4.2. The Chisinau Eco-Agricultural Economy: Position and Circular Potential

Moldova's ecological agriculture sector has undergone significant institutional and quantitative growth since 2020, repositioning itself as a credible component of the country's circular economy development trajectory. The number of ECO-certified agricultural producers has grown from 38 enterprises in 2020 to 151 producers holding ECO certificates covering approximately 50 agricultural crops (UN Development Programme), with the area cultivated under organic certification estimated at approximately 26,000 hectares. Despite this expansion, organic farmland still represents only around 1% of Moldova's total arable land, well below the government's stated ambition of achieving 25% organic conversion by 2030. The product mix remains skewed toward tree crops and perennials, with 12 honey-producing enterprises certified in the animal production category as of early 2024 (Seerural), a marginal improvement that nonetheless leaves certified vegetable, fruit, and broader animal production severely under-represented. On the legislative side, a landmark reform occurred with the adoption of Law No. 237/2023 on organic production and labelling, which entered into force on 1 July 2024 (Seerural), aligning Moldova's regulatory framework with EU Regulation 2018/848, a prerequisite for the mutual recognition of Moldovan organic certificates on European markets. Government Decision No. 433/2024 on the organic production control and certification system (STC) further operationalised these reforms. International market positioning has advanced: Moldova participated in BIOFACH 2025 with a record national stand double the size of previous editions, with eight companies presenting certified organic honey, wines, cold-pressed oils, plums, nuts, bio flour, and cereals and the country now exports over 40,000 tonnes of organic products to the EU annually Gov. On the retail side, the Chisinau food market has expanded substantially: the turnover of the ten largest retail chain operators in Moldova reached €1.55 billion in 2024, representing a 23.4% increase over 2023, and 521 of the country's 940 chain retail outlets are concentrated in the capital, confirming Chisinau's enduring dominance as the primary commercial market for eco-products. This market concentration makes Chisinau simultaneously the most viable location for eco-product commercialisation and the site where regenerative agriculture's circular economy potential can most readily be demonstrated, validated, and scaled.

The informal agricultural sector remains a structural feature of Moldova's rural economy, though its composition and policy context have shifted materially since 2017. The share of employment in the informal economy has reached 56% in 2022, one of the highest rates in the Central and Eastern European region, while informal employment in agriculture specifically stands at 44%, with over 56% of agricultural workers lacking formal contracts and thus excluded from pension, sickness, and unemployment protections Moldpres. Moldova's agricultural workforce has contracted sharply, from approximately 770,000 workers in 2000 to an estimated 179,000 in 2023, a decline of roughly 78%, reflecting persistent rural poverty, low wages, seasonal precarity, and emigration. According to the NBS Labour Force Survey 2024, 18.1% of Moldova's total workforce remains employed in agriculture, underscoring the sector's continued centrality despite its structural fragility. Smallholder and family farms account for 98.8% of all agricultural producers and cultivate 36.4% of agricultural land, generating over 62% of total agricultural produce, a production base whose low-external-input character makes it intrinsically aligned with regenerative agriculture principles, even if not yet formally certified. This reservoir of potential regenerative practitioners is, however, increasingly constrained by demographics: Moldova's ageing rural population, with over 50% of rural inhabitants aged above working-age norms, and high emigration continue to shrink the agricultural workforce, making collective organisational structures an economic necessity rather than merely a policy preference.

The legal environment for collective formalisation has strengthened considerably. Building on the Agricultural Producer Groups Law of 2020, 54 Local Action Groups are now active across the country, covering over 61% of Moldova's territory and more than 1.14 million citizens. The National Agricultural and Rural Environment Development Fund has recorded a 70% increase over four years, reaching a record 1.9 billion lei in 2025, with over 8,200 unique farmers, including approximately 2,900 women and young people benefiting from subsidies, and micro-farmers now representing 61% of fund beneficiaries. Crucially, allocations for young farmers, women farmers, producer groups, and entrepreneurial cooperatives were explicitly increased in the most recent legislative reform cycle, reinforcing the policy architecture for collective transitions to ecological and regenerative production. The overarching strategic framework has also been renewed: the National Strategy on Agriculture and Rural Development 2023–2030 is now the governing policy document, partially aligned with the EU Common Agricultural Policy FiBL, and the Agrifood Partnership Platform, launched in October 2023 by the Ministry of Agriculture together with the EU Delegation and FAO, formalised a Joint Declaration supporting Moldova's agri-food sector on its path toward EU membership. Moldova's October 2024 constitutional referendum, which anchored EU membership as a strategic goal in the constitution, further institutionalises the trajectory toward EU-aligned ecological production standards, including the organic regulation framework introduced by Law No. 237/2023, as the definitive long-term direction for the sector.

4.3. Climate Change as a Driver of Circular Water Imperatives

Moldova's climate trajectory makes the transition from linear to circular water management a matter of economic survival rather than merely good practice. Historical temperature records show that 7 of the 10 hottest years on record in Moldova occurred in the last two decades. Agricultural droughts now regularly span entire growing seasons. The Dniester River, which supplies approximately 80% of Moldova's total water needs and 98% of the water received by the capital Chisinau, is under compounding anthropogenic, climatic, and now direct war-related pressures. The Novodnestrovsk hydroelectric complex has chronically reduced natural flow regimes to 120–130 cubic metres per second in critical sections, versus the natural norm of 220–260 cubic metres per second, and the river's self-purification capacity has declined by an estimated 80% over three years.

The latent contamination risk from Ukraine's Dniester basin, previously attributed to 25 Soviet-era toxic waste deposits storing 165 million tonnes of industrial hazardous material, escalated into an acute crisis in March 2026. On March 2026, Russia carried out its first large-scale missile and drone attack on the Dniester Hydroelectric Power Plant in Chernivtsi Oblast, Ukraine. Slicks of technical transformer oil were discovered in the Dniester near the village of

Liadova in Ukraine's Vinnytsia Oblast, with the pollution confirmed to have originated from infrastructure damaged by the Russian strike. The oil slicks drifted downstream and were confirmed within Moldova's territory near Naslavcea, prompting Moldova's Environment Minister to warn that the actual volume of oil in the river significantly exceeded the initially reported 1.5 tonnes, and that pollutants were still actively entering the river. As a result, Moldova's government activated the EU Civil Protection Mechanism, deployed absorbent booms and containment barriers at critical intake points including near the Vadul-lui-Voda water intake station that supplies Chisinau, and water supply was restricted in northern regions as a precautionary public health measure. It is to be mentioned that since early October 2025, Russian forces have deliberately attacked 11 hydroelectric power plants and 45 major combined heat and power plants across Ukraine (UNCTAD), making the Dniester contamination not an isolated incident but the latest manifestation of a systematic strategy of environmental destruction with transboundary consequences.

This March 2026 crisis transforms what was previously a latent risk scenario into a documented, recurring threat category for Chisinau's water supply and, by extension, for every eco-enterprise in its downstream agricultural value chain. In circular economy terms, the river remains the ultimate upstream node of the regional water loop: its acute contamination by war-related petroleum products, layered upon chronic flow mismanagement and Soviet-era industrial waste legacies, constitutes a compounding systemic value destruction that no individual water utility or farm operator can absorb or offset. Restoring the Dniester's ecological integrity, through transboundary governance, military conflict resolution, and the regenerative upstream agricultural practices described throughout this study is therefore not merely an environmental goal but an existential economic prerequisite for the entire downstream regenerative agriculture and circular economy transition in Moldova.

4.4. Score-Based Risk Assessment and Circular Economy Reinterpretation

The Chisinau water supply system is a linear throughput system in its current configuration: water is extracted from the Dniester, treated through coagulation-flocculation-sedimentation-filtration-chlorination, distributed to users, and discharged as wastewater with minimal recirculation. The system was designed for Soviet-era consumption volumes; current use represents approximately 25% of historical peak demand, creating structural overcapacity that nonetheless masks significant vulnerability due to aging equipment and single-source dependence. Water quality monitoring at the intake section reveals average E. coli counts of 245 UFC per 100ml and total coliform counts of 334 UFC per 100ml, requiring full multi-stage treatment before distribution.

From a circular economy perspective, each risk identified in the assessment below corresponds to a failure point of this linear model. The risk assessment simultaneously serves as a diagnostic of where circular economy interventions, at the governance, infrastructure, and enterprise levels, would generate the greatest resilience returns. The reinterpretation of each risk through a circular economy and regenerative agriculture lens is an analytical contribution of this paper, connecting technical risk management to the broader paradigm shift.

The intake stage from the Dniester River carries the highest concentration of maximum composite risk scores. Seven principal hazards at this stage register initial scores between 20 and 25 out of 25. Table 1 presents the assessment including circular economy and regenerative agriculture intervention pathways, demonstrating how each risk corresponds to a design failure of the linear system and how circular or regenerative interventions address it at source.

Table 1. Risk Assessment at Water Intake Stage: Circular Economy and Regenerative Agriculture Intervention Pathways

Hazard (Initial Score)	Init.	Current Controls	Treat.	CE / Regenerative Agriculture Intervention Pathway
Dniester level below minimum intake (Prob-5, Sev-5)	25	Reservoir discharge management; minimum flow 190 m3/s	20	Establish Dniester River Administration (governance circularity); upstream regenerative agriculture to restore hydrological base flows; riparian reforestation for evapotranspiration regulation
Atypical toxic substances with unknown treatability (Prob-4, Sev-5)	20	Pump shutdown protocol; visual intake screening	15	Bio-indicator organisms (freshwater mussels) as circular biosensors; constructed wetland pre-treatment as natural circular filter; upstream toxic waste remediation programme
Dniester level above maximum intake - flooding (Prob-5, Sev-5)	25	Stop intake pumps; drainage pumps; existing emergency protocol	10	Fluvial administration with real-time discharge scheduling; upstream reforestation to attenuate flood peaks (regenerative hydrology)
Excessive turbidity - siltation (Prob-5, Sev-5)	25	Pump shutdown to prevent siltation; sludge washing protocol	10	Upstream regenerative agriculture (cover crops, no-till) to reduce soil erosion and sedimentation, directly reducing turbidity at source; settling pond as circular recirculation node
Power supply interruption (Prob-5, Sev-5)	25	Transfer to own power source; emergency protocol	10	Renewable energy integration (solar/wind) for circular energy self-sufficiency at pumping stations; gravity-fed circular distribution design alternatives
Nitrates and nitrites above norm - rising probability with climate change (Prob-2, Sev-4)	8	Pump shutdown; water quality monitoring	8	Upstream regenerative agriculture (precision nutrient management, legume cover crops, riparian buffer strips) eliminates the risk at source rather than managing it at end of pipe; eliminates need for costly anionite filtration stage
Qualified personnel shortage (Prob-5, Sev-5)	25	Detailed step-by-step operational procedures; motivating salary for suburban location	5	Circular digital infrastructure: remote IoT monitoring, SCADA with biosensor integration; reduces human labour dependency at remote locations

Source: Own elaboration based on Apa-Canal Chisinau operational data; CE/RA intervention pathways represent the authors' analytical contribution.

Two risk items merit particular attention through the regenerative agriculture lens. The turbidity risk (scored 25/25 initially, treated to 10/25) and the nitrate risk (scored 8/25 and unchanged by current controls) are primarily driven by upstream agricultural practices: conventional tillage, synthetic fertiliser over-application, and the absence of riparian buffer zones. A regional transition to regenerative agriculture practices upstream of the Chisinau intake would reduce these risks at source, dramatically outperforming end-of-pipe treatment solutions in both cost effectiveness and ecological benefit. This is the circular economy principle of regenerating natural systems applied concretely: soil health restoration generates measurable downstream water quality benefits that reduce infrastructure risk scores throughout the entire supply chain, while simultaneously building the productive capacity and climate resilience of the agricultural sector itself.

At the transmission stage covering aqueducts of 1,400 to 2,000 mm diameter, key risks including pipeline rupture (initial 25/25, treated 20/25) and pathogen contamination through structural cracks (initial 25/25, treated 5/25 under current chlorination) point toward the circular infrastructure principle of designing for durability, repairability, and minimum material throughput. Leakage losses, which in many post-Soviet water systems represent 30 to 50% of treated water volumes, constitute a critical value leak in circular economy terms: treated water embodying significant energy and chemical inputs is lost before reaching end users. Digital leak detection technologies and pipe rehabilitation investments represent circular infrastructure upgrades with positive returns across energy, water, and financial dimensions simultaneously.

At the treatment stage, the nitrate risk (initial 8/25, treated 8/25, unchanged by current controls) reflects the fundamental limitation of end-of-pipe treatment for diffuse agricultural pollution. A standard anionite filtration stage could reduce this risk but would require significant capital investment and ongoing chemical inputs. The circular economy alternative, reducing fertiliser run-off through upstream regenerative practices, achieves equivalent risk reduction while simultaneously building soil carbon, reducing farmer input costs, and preserving natural nutrient cycles. This cost comparison, between adding a treatment stage downstream and investing in regenerative practices upstream, exemplifies the economic logic of moving from linear risk management to circular systems design.

In the distribution network, the highest residual risk is water supply insufficiency during peak demand or drought periods (initial 20/25, treated 16/25). This risk has no purely technical solution within the current linear system, as it reflects a structural imbalance between fixed infrastructure capacity and variable seasonal demand. A circular demand-management approach combining enterprise-level closed water loops, distributed rainwater harvesting at building and farm level, and legislative restriction mechanisms for peak periods could reduce effective demand sufficiently to relieve system pressure. This aligns with the circular economy principle of keeping resources in use at highest value, applied here to water volume management rather than material flows.

The Conan-Holder model provides a framework for assessing how water supply disruptions affect the financial health of Moldovan SMEs in the eco-agriculture sector. The composite score Z = 0.24R1 + 0.22R2 + 0.16R3 minus 0.87R4 minus 0.10R5 evaluates enterprise viability, where R1 measures own financing capacity as gross operating surplus over total debt, R2 measures patrimonial solvency as permanent capital over total assets, R3 measures working asset efficiency as current assets minus stocks over total assets, R4 measures financial cost burden as financial charges over turnover, and R5 measures labour remuneration intensity as personnel costs over value added.

Table 2. Conan-Holder Failure Risk Grid: Circular Economy Resilience Levers for Moldovan Eco-SMEs

Z Score	Enterprise Situation	Failure Risk	Circular Economy Resilience Lever
Z > 0.16	Very good	< 10%	Reinvest surplus in closed-loop water infrastructure
0.10 < Z < 0.16	Good	10-30%	Adopt aquaponic or hydroponic systems to reduce water cost exposure
0.04 < Z < 0.10	Alert	30-65%	Emergency water storage; diversify sources through rainwater harvesting
-0.05 < Z < 0.04	Danger	65-90%	Transition to regenerative practices reducing irrigation dependence
Z < -0.05	Failure	> 90%	Co-operative pooling via Agricultural Producer Group

Source: Conan and Holder (1978), adapted with circular economy resilience pathways by the author.

Water supply disruptions affect Moldovan eco-SMEs primarily through R3 (inventory and current asset losses from production stoppages), R1 (reduced operating surplus from lost revenue), and potentially R4 (emergency water procurement raising financial charges). The circular economy adaptation visible in Table 2 is that each Z-score zone has a corresponding circular economy resilience lever: rather than merely absorbing shocks, circular economy-aligned enterprises structurally reduce their exposure to water-driven financial volatility by closing water loops, reducing net consumption, and diversifying water sources. This transforms water risk management from a cost centre into an investment in resilience that simultaneously lowers both the probability and severity of financial distress.

Additionally, aquaponic systems represent the most complete circular economy application available in the agri-food context. Fish provide organic fertilisation for plant growth, eliminating synthetic fertiliser costs. Plant roots biologically purify fish water, eliminating water discharge treatment costs. The net water consumption of the closed loop is near zero, eliminating irrigation water costs and supply disruption exposure simultaneously. The Salamer-Com LLC case in Moldova demonstrates commercial viability at small scale: lettuce and other crops are grown in an aquaponic system, with fish providing organic nutrient cycling and plant roots performing biological water purification. The economic logic aligns precisely with circular economy value creation theory: internalising previously externalised resource flows (nutrient management, water treatment) generates cost savings that exceed the investment required to close the loop.

Constructed wetlands represent a regenerative agriculture-compatible circular infrastructure investment with multiple co-benefits. They treat greywater and lightly contaminated agricultural runoff through natural biological processes, producing treated water suitable for irrigation, thereby creating a second-loop circular water supply that reduces dependence on the linear municipal system. Constructed wetland treatment costs are typically 50 to 80% lower than conventional wastewater treatment per unit volume, and the systems simultaneously provide biodiversity habitat, carbon storage, educational value, and landscape aesthetic quality consistent with regenerative enterprise positioning and eco-tourism development.

The Orhei-Vit canning company's documented achievement of a 20% water consumption reduction through automatic valve installation, generating USD 345,000 in annual savings, illustrates the circular economy principle of doing more with less through intelligent design rather than resource substitution. Scaling this logic to circular water system design that integrates rainwater harvesting with greywater recirculation and closed-loop production processes would generate savings proportional to water intensity while reducing supply chain vulnerability. Romania's national irrigation infrastructure rehabilitation programme confirms the macroeconomic scale of these returns: investments generate net benefits of approximately 19,580 thousand euros per 100,000 hectares through productivity improvements and crop optimisation.

5. Conclusions

This study has demonstrated that the interplay between regenerative agriculture and circular economy principles is most tangibly expressed, in the Moldovan context, through the governance and management of water as a shared circular resource. The score-based risk assessment reveals that critical barriers to water security for eco-enterprises in Chisinau operate at multiple scales simultaneously: at the basin scale through Dniester flow mismanagement and transboundary toxic waste risks, at the infrastructure scale through aging linear throughput systems and single-source dependence, and at the enterprise scale through insufficient adoption of closed water loop technologies.

The regenerative agriculture and circular economy frameworks provide not merely a theoretical overlay but an actionable solution architecture for each identified risk category. Regenerative upstream agricultural practices reduce turbidity and nitrate risk at source, outperforming end-of-pipe treatment investments in cost-effectiveness and ecological co-benefit generation. Circular water technologies at the enterprise level transform water from a single-use linear input into a continuously recirculated resource, dramatically reducing both supply disruption exposure and operating costs. Governance circularity, the creation of feedback loops between enterprise practices, local water management, and basin-scale institutional coordination, is the systemic precondition for both.

The following policy recommendations are advanced. First, the establishment of a Dniester River Administration with legal authority to monitor, schedule, and coordinate extractions, reservoir discharges, and emergency responses is the highest-priority governance reform. This body should operate on principles of integrated adaptive water resource management consistent with the EU Water Framework Directive, and should publish real-time hydrological data modelled on Romania's INHGA diagnostic and prognostic system.

Second, national agri-environmental support schemes should explicitly incentivise regenerative agriculture practices including cover cropping, no-till cultivation, and riparian buffer establishment as upstream water quality and flow management interventions, recognising their ecosystem service value for downstream water users throughout the Chisinau eco-enterprise ecosystem.

Third, circular water infrastructure including aquaponic systems, rainwater harvesting, greywater loops, and constructed wetland treatment should be classified as eligible investments in FDD Moldova infrastructure financing rounds and in the BNM credit risk mitigation framework under Regulation No. 112/2018, with risk-adjusted return calculations that incorporate the monetised value of water disruption risk avoidance.

Fourth, Water Safety Plans mandated by Law No. 182/2019 on Drinking Water Quality should be extended to include enterprise-level circular water plans for eco-certified producers, creating a standardised framework for water circularity assessment and continuous improvement integrated within the ecological certification system.

Fifth, legislative frameworks enabling demand management during drought or peak periods should be enacted, recognising that circular demand reduction at the consumer and enterprise level is as important as supply-side management for systemic water resilience.

Moldova's geographic position, its EU Association Agreement obligations, and the growing global premium for traceable, regeneratively produced food create a genuine strategic opportunity. The country's transition toward the regenerative agriculture and circular economy nexus requires above all a secure water governance foundation: without it, the most sophisticated circular water technologies and the most committed regenerative farmers remain exposed to systemic risks that no individual enterprise can manage alone. Resolving Moldova's water governance crisis is, therefore, the indispensable first step toward realising the full economic and ecological potential of the regenerative agriculture and circular economy transition.

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