The Influence of "Modernising the Farming Process" on the Food Systems and the Export in the Agricultural Sector in the Northern and Western African Regions

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Abstract. This article infers the best explanation of *"modernising the farming process"* or MFP" in Northern and Western Africa (NWAR). The theory of peasant economy guides the inference of the best explanation of "MFP". This purpose involves the hypothetico-deductive method through random effects modelling and systems dynamics simulation. Thus, NWAR form the sample constructed on the secondary dataset between 2011 and 2020. The findings revealed that "MFP" is a necessary and sufficient condition for these regions' food systems and exports. Moreover, agricultural policy is associated with "MFP" in both regions, even though it is a necessary albeit insufficient condition. Consequently, as agricultural policy impacts "MFP" and the latter is associated with food systems and exports, the conclusion is that "MFP" calls for an impetus in both regions regarding agricultural extension policy.

Keywords: modernising the farming process; food systems; agricultural policy; export; Northern and Western African regions.

1 Introduction

"Modernising the farming process" (abbreviated "MFP" in the following sections) could serve food systems and export in Northern and Western Africa (NWAR) with a set methodology. This study defines "MFP" using rigorous thinking and inquiry to examine NWAR farmers' worlds from many perspectives. In these regions, "MFP" links intellectual disciplines to sustain innovation in the agriculture sector [1] to understand how and why these emerging regions evolve [2]. The article recommends modernising food systems using organisational, process-related, and technological means to boost exports. Due to their emergence in growing economies, "MFP" is crucial in NWAR [2], with a regional annual average of 12.9% in Northern Africa (NA) and 27.6% in Western Africa (WA) between 2011 and 2020 [3]. Since the regional annual average of water stress between 2011 and 2020 is 222.5% in NA against 5.3% in WA [4] and family farms are prevalent [5], "MFP" may solve food shortages, climate change, and environmental concerns in NWAR by increasing food systems.

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In Marx's capitalist production system, the low-wage labour force, commodities market, and capital (re-)investment as means of production limits labour value expansion, which is key to harvesting surplus value [6]. African countries, where agriculture is the dominant economic sector, have lower wages than Asian countries where manufacturing dominates, or Western European countries where services dominate [7, 8]. Donating to farmers or their farming goods for lengthy periods reduces savings, investment, and labour-intensive competitiveness [7]. Thus, it may slow growth and hurt farm income, poverty reduction, and exports [7, 9].

"MFP" [5, 10, 11] could profit from agricultural exports to the world market by adopting organisational modernisation [11] or farm-level trade technologies [7]. African policymakers are also interested in "MFP" because it could improve family farming investment [5, 11] or apply for technological advances [8] in capital, labour, skills, and a mixed package of inputs investments at upstream farming systems, which account for more than 60% of total factor productivity (TFP). TFP guides economic growth [8], whereas NA's regional average of agrarian TFP climbed 3.9% between 2008 and 2013 from 0.7% between 2006 and 2011. WA TFP increased by 2.7% from 1.6%. The TFP of WA rose by 2.4% and NA rose by 1.3% between 2007 and 2012 [13]. The 'pre-Newtonian science' is still inapplicable to farmers [14] because they allocate their resources to the agrarian system within the hierarchical social structure, which becomes a fatalistic value system to inherit land from grandparents and pass it on to grandchildren. High-labour countries with low education and skills tend to turn to agriculture [8], which complicates trade or pricing policies and reveals agricultural economic sector conflicts [7, 15].

Technological advances are expected to benefit agriculture despite farmers' lack of access [8, 15]. Trade technology will aid landlocked WA states, as Burkina Faso, Mali, and Niger [16], which lack absolute advantage but have comparative advantage [7].

The NWAR makes learning part of agriculture's innovation process [17]; hence, the "MFP" conceptual framework is crucial for learning. This essay also assesses which "MFP" approach could help farmers in these places attain food systems and exports.

Given the circumstances, these questions guided this research:

Question 1: How does a component of "MFP" affect the food systems in the NWAR?

Question 2: To what extent can "MFP" affect the export in the NWAR?

Question 3: What are the enablers' policies for "MFP" that need to be recommended in the agricultural sector as most suitable for the NWAR?

1.1 Operationalisation of 'MFP' and the level of NWAR

Table 2 indicates that "MFP" includes everything needed to utilise and reorganise downstream and upstream farming production systems [4, 10, 11]. MFP faces problems such as low regional annual average salaries of 3.9% and 6.9% in NA and WA between 2011 and 2020 [4], poverty, food insecurity, and climate change [18]. Between 2011 and 2020, farming firms employed 26.6% in NA and 37.5% in WA, with 24.6% and 38.5% female workers [19].

While "MFP" expands the change rate [1], its operationalisation contains facilitators such as level of input usage and technique [20]. Due to their robust and consistent effects on agricultural transformation, process method, and organisational modernisation, input usage intensification and farm size increase the inverse productivity relationship between farm size and productivity [4, 11, 17, 20]. Upstream farms regulate land, water, personnel, credit, seeds, and fertiliser application rates. The downstream stage involves drying, fermentation, sterilisation, and storage, which require credit to buy modern inputs [1, 10, 20, 21] to increase output. NA averaged 81.4% water use and WA 58.6% in 2011–2020. NA and WA averaged 31% and 39.9% soil and land use in 2011–2020 [22].

Technological advances enable "MFP" functioning. For food system productivity and export, technical modernisation must include product processing or market placement [1, 7, 8, 9, 15, 17, 20, 21].

Public investment as inputs for agricultural GDP returns from (primary) education or agrarian R&D is another operationalisation of "MFP" [21, 23, 24]. Extension of services boosts productivity when backed by other measures. Rural electrification, irrigation, and roads are critical public investments that boost "MFP", including producing modern seed types that are more responsive to inorganic fertiliser and gender [21, 23]. Public education spending in NA and WA averaged 4.5% and 4% from 2011 to 2020 [25].

Skills, technology (certified seed of improved varieties and hybrids, (inorganic) fertiliser), access to capital, and logistics for trading, marketing, and storage require credit [17, 21]), but "MFP" operationalisation still faces obstacles in its change rate, organisational modernisation, or agrarian sector processes. Between 2011 and 2020, skilled agricultural, forestry, and fisheries (AFF) workers averaged 35.6% in NA and 24.4% in WA [25], as presented in Table 1.

Operationalisation of "MFP" in terms of methods, organisational modernisation, and technological modernisation is likely to increase TFP growth, which is the ratio of total output (crop and livestock products) to total production inputs (land, labour, capital, and materials) [13], which ensures production improvements with scientific innovation, adoption of new and existing technologies, and technological advancement [8]. Using "MFP" in NWAR would also account for net capital stock, which averaged USD 16,425.6 million and USD 11,917.7 million in NA and WA between 2011 and 2020. Annual agriculture training workers in NA and WA averaged USD 0.91 million and USD 1.01 million. Farmers' co-operatives averaged USD 1.25 million in NA and USD 1.23 million in WA during that period.

AFF credit averaged $1,376.7 million in NA and $304.2 million in WA. Water and soil conservation techniques were 12,480,348.6 in WA and 16,377,098.2 in NA. During 2011–2020, fertiliser averaged 862,558.6 tonnes in NA and 199,790.9 tonnes in WA, whereas seeds averaged 1177446.2 tonnes and 110932.2 tonnes [4, 10, 11, 22].

1.1.1. The level of NWAR

The NWAR is meant to operationalise the conceptualisation of "MFP" because they have features such as growing economies [2] and family farms [5] that might lead to environmental or food shortages. Despite being on the same African continent, these regions differ in organisational modernisation (process technique) and technological modernisation (advanced application of technology frontier), which affect the TFP. This study links intellectual disciplines and agricultural innovation [1] to comprehend how and why NWAR emerge through hunger and environmental impacts.

Hunger Level

The countries of NA are Algeria, Egypt, Libya, Morocco, Sudan, and Tunisia. The countries of WA are Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo. The two regions are overall coastal except for landlocked Burkina Faso, Mali, and Niger [16].

NA had 10.2% real GDP in manufacturing (beverage, food, and tobacco) value added in 2011 and 2020, while WA had 9.7% [19]. NA's average real GDP growth in AFF was -0.4% between 2011 and 2020, while WA's was 5.1% [19]. Thus, between 2011 and 2020, the regional yearly averages of the global hunger index (GHI) in NA and WA were 11.4% and 21.5%, respectively, with moderate and considerable hunger [27, 28, 29, 30, 31, 32, 33, 34, 35, 36]. With regard to financial performance, WA had an annual average of agriculture value added per worker of USD 3,068.7 compared to USD 7,400.1 in NA between 2011 and 2020 [19]; World Bank, 2021], which is more likely to explain the regional average of export of USD 1,816,008.5 in NA and USD 954,581.7 in WA [19].

World market exports and "MFP" are not primarily responsible for progress in these places. However, smart policies can balance market efficiency with social compassion [38]. Examples are social priority spending of 50%, moderate public spending of 25%, and social sector spending of 40% or higher [38]. Residents' average income is expected to boost local marketplace means, leading to socio-economic expansion in rural NWAR and modernised agriculture sector economy. The latter aids food systems and exports. To eliminate hunger in North Africa (<5 in Algeria, Egypt, Libya, or Tunisia) in 2010, domestic investments in agriculture, food reserves, trade agreements, and protectionism should lower the food trade deficit [39]. This article addresses this issue by conceptualising "MFP" in the NWAR.

Environmental Repercussion

Farmers' problems and environmental impacts weaken complicated systematic farming production systems, including increased prices, which harms food systems. Besides the ecosystem's threat, water's importance to food chains makes it worse. Algeria, Egypt, Sudan, and Tunisia had 100% and 150% water stress between 2009 and 2017, while Libya had 817%. [4]

Climate change adaptive capacities cost between USD 4 billion to USD 109 billion each year globally, even though each state must endorse [40]. The negative impact on farming systems in WA caused millet and sorghum yield losses of 10.9% and 17.5%, or USD 1.65 and 2.99 billion, and 5.9% and 15.0%, or USD 0.69 and 1.89 billion, respectively [41]. This caused cereal yield losses of over 50% in the Northern Sahel, which produces 59% [41].

Thus, "MFP" is needed in the NWAR to improve agricultural exports and food systems in both rate of change and technological modernisation.

Table 1. Summary of the financial, environmental, and social performances in the Northern and Western Africa regions, annual average between 2011 and 2020

Financial, environmental, and social performances in the Northern and Western Africa regions, annual average between 2011 and 2020												
Regions		*Annual average in percent between 2011 and 2020*								*Annual average in USD prices between 2011 and 2020*		*Annual average of hunger in scale between 2011 and 2020*
	Country type	Agriculture employment	Female labour in agriculture	Farmers wages	Water stress	Real GDP in AFF	Real GDP in manufacturing	GDP annual growth in AFF	GDP annual growth in manufacturing	Agriculture value added per worker	Export, USD	GHI
Northern Africa												
Algeria	*Coastal*	9.5	6.1	3.4	123.2	11.3	4.5	5.4	1.5	17066.8	357775.3	7.5
Egypt	*Coastal*	25.7	27.6	10.3	120.7	11.3	16.3	3.7	5.9	4909.9	4735225.2	10.3
Libya	*Coastal*	26.6	24.6	3.9	817.1	0.7	2.7	-9.4	25.5	4250	13395.6	8.8

Morocco	*Coastal*	38.5	38.9	-1.6	50.8	12.6	15.6	2.5	2.6	3370.1	2908123.6	7.8
Sudan	*Coastal*	44	31.2	3.9	118.6	32.2	6.7	-7.4	-3.1	7062	1361757.4	28.3
Tunisia	*Coastal*	15.4	18.9	3.7	104.7	9.6	15.4	2.5	-2.5	7742	1519773.8	5.8
Western Africa												
Benin	*Coastal*	37.5	38.5	-4.5	1	25	11.2	10.6	4.7	1247.7	479037.2	19.4
Burkina Faso	*Landlocked*	27.1	38	-2.7	7.8	22.9	10.6	4	3.4	1884.5	671736.9	24.6
Cape Verde	*Coastal*	12.9	27.2	-1.4	8.4	7.3	6.2	-3.8	4.7	6523.8	1789	11.6
Ivory Coast	*Coastal*	44.2	37.3	19	5.2	18.5	12.8	8.1	9.7	2501.4	7060161.3	22.2
Gambia	*Coastal*	19.5	52.5	9	2.2	22.2	5.7	-4.2	1.5	2468.2	18364.4	18.6
Ghana	*Coastal*	35.2	43.4	25.1	6.1	20.3	12	0.7	2	3810.7	3214873.7	12.4
Guinea	*Coastal*	37.5	38.5	0.4	0.9	17.8	13.6	9.8	7	4250	155191.9	23
Guinea-Bissau	*Coastal*	37.5	38.5	-1.5	1.5	47	10.5	7.6	5.8	4250	187457.9	23.7
Liberia	*Coastal*	37.5	38.5	6.9	0.3	55.6	4.8	12.6	7.2	4166.2	186491.1	27.2
Mali	*Landlocked*	65.6	44.8	-0.5	8	36.3	14.5	7.6	7.4	1577.1	496612	22.5
Mauritania	*Coastal*	31.9	28.4	6.9	13.2	20.8	7.5	4.7	5.1	4249.3	24068.4	19.7
Niger	*Landlocked*	52.6	19.8	9.8	6.7	34.8	6.6	6.9	8.2	2214.7	335547.9	27.8

Nigeria	*Coastal*	37.5	38.5	31.8	9.7	21.5	8.9	2.6	11.7	4292.4	1492281.6	23.3
Senegal	*Coastal*	33.2	34.6	0.1	10.7	14.3	17.2	4	2.4	1817.9	619112	16.5
Sierra Leone	*Coastal*	57	52.3	9.8	0.5	55.1	1.7	6.3	3.8	1683.8	53880.7	30.5
Togo	*Coastal*	33.8	45.3	1.8	3.4	22.7	11.8	3.8	17.6	2161.7	276701.9	20.8

	Regional annual average										
Region	*Annual average in percent between 2011 and 2020*								*Annual average in USD prices between 2011 and 2020*		*Annual average of hunger in scale between 2011 and 2020*
	Agriculture employment	Female labour in agriculture	Farmers wages	Water stress	Real GDP in AFF	Real GDP in manufacturing	GDP annual growth in AFF	GDP annual growth in manufacturing	Agriculture value added per worker	Export, USD	GHI
Northern Africa	26.6	24.6	3.9	222.5	12.9	10.2	-0.4	5	7400.1	1816008.5	11.4****
Western Africa	37.5	38.5	6.9	5.3	27.6	9.7	5.1	6.4	3068.7	954581.7	21.5***

Notes: GDP is gross domestic product; AFF is agriculture, forestry, and fishery value added; USD is US currency; GHI is global hunger index.
Notes: * ≥ 50.0 indicates extremely alarming hunger; ** 35.0-49.9 alarming hunger; *** 20.0-34.9 serious hunger; **** 10.0-19.9 moderate hunger.

Source: [3, 4, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37]

1. 2. Conceptual models of the systems thinking of "MFP" in the NWAR

Figure 1 shows how food systems and agricultural exports in the NWAR (partially due to the rate of change in improved inputs with innovative techniques and advanced application of technology frontier in water, forest use, education, and training, or human and material capital) will affect intensive mixed farming. Mixed farming can include mono- or poly-culture farming of edible or inedible plants, as fruit or wild trees, to enhance biodiversity, animal husbandry, fish farming, or related subsistence crops; grains for the local countryside market; cereals for domestic, regional, and international markets; and non-grain food cash crops such as Roundwood.

Improved harvesting systems or mechanised combine harvesters as the process method in dynamics organisational modernisation of the agricultural sector should produce practical changing outputs and create a causal loop of agriculture production systems, added-value, and derived products under food systems.

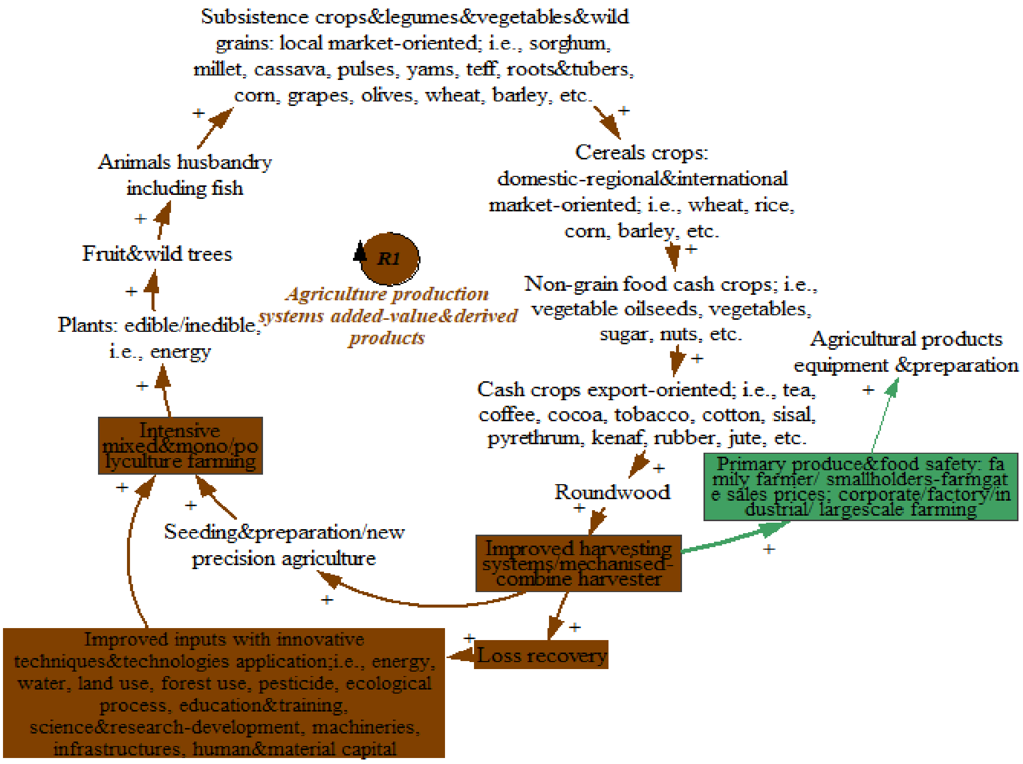

Fig. 1. Systems thinking models of a reinforcing causal loop (R1) of agriculture production systems, added-value, and derived products under *"modernising the farming process"*.

(Source: Authors' creation.)

In the meantime, improved harvesting systems may improve primary produce and food safety for family farmers or industrial large-scale farming, which spurs agricultural product equipment and preparation for food transformation, cleaning, grading, improved food packing, or the end product of primary food, creating a balancing causal loop of post-harvest added-value and distribution.

The storage process allows the food industry stage or ultra-processed food items to reach food transformation, creating a reinforcing causal loop to increase food processing added-value and distribution. However, innovative harvesting devices may increase loss recovery process catalysis for improved inputs.

The end product of primary food is likely to affect home farm output for consumption or domestic market purposes, food wholesaling, retailing, or food services and catering added value, creating a reinforcing causal loop of local food systems' added-value chain and countryside's viable economy. This could also affect food costs in the countryside due to home farm output for consumption and the domestic market, while the food business would raise food fortification with health risks. Ultra-processed food will improve distribution and safety (see Figure 2).

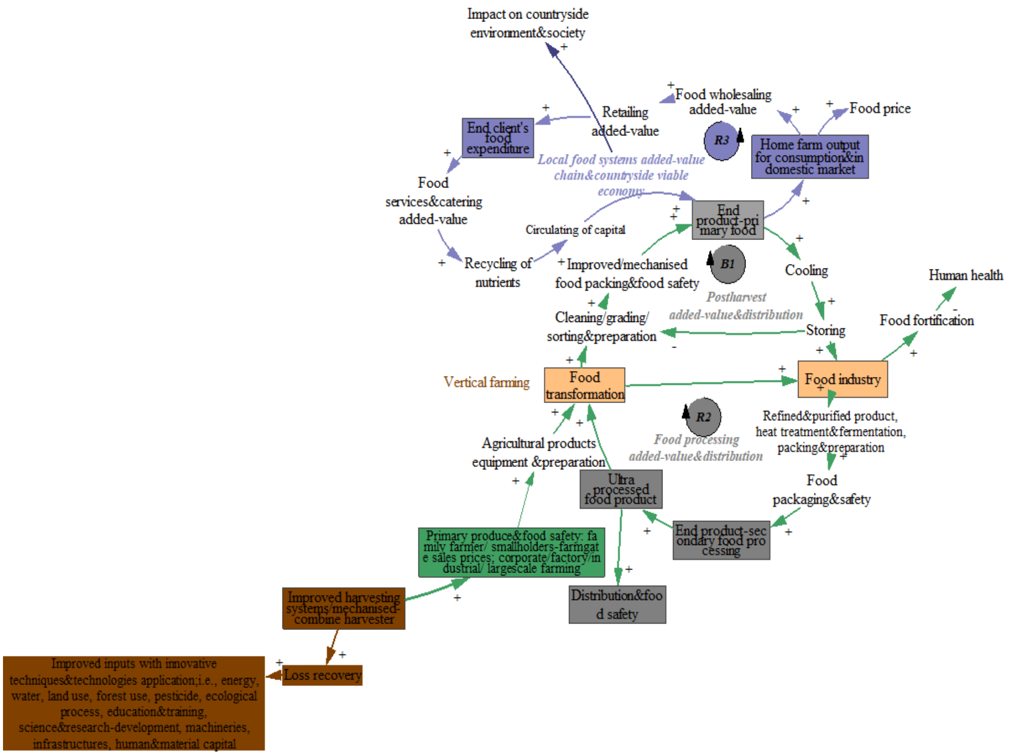

Fig. 2. Systems thinking models of a balancing causal loop (B1) of post-harvest added-value and distribution, a reinforcing causal loop (R2) of food processing added-value and distribution, and a reinforcing causal loop (R3) of local food systems' added-value chain and countryside's viable economy under *"modernising the farming process"*.

(Source: Authors' creation)

Thus, secondary food processing could enable farming output that increases new capital formation in the agricultural sector, economic incentives, Foreign Direct Investment (FDI), policies, or digitalisation, including the power of information or big data to enhance seed priming and agronomic practices such as fertiliser application or selective breeding to create a bio-fortification loop.

Individual and national food self-supply, employment creation, and digital technologies are equally important. This increases food security and nutrition supported by food aid and services or hunger, food exports, and imports (raw and processed), creating a trade-off added-value loop that reinforces global food systems and national economies (refer to Figure 3).

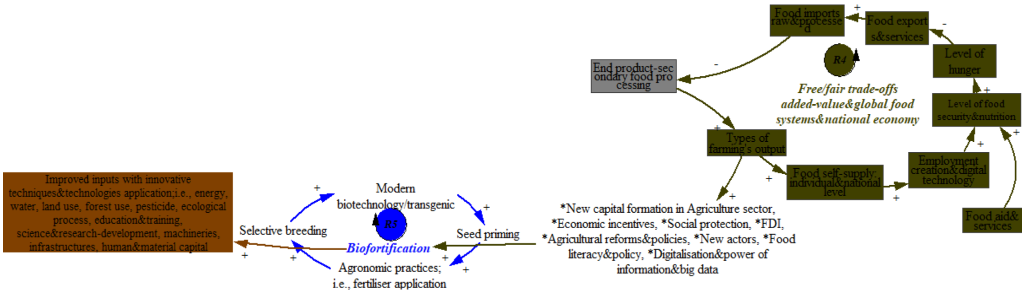

Fig. 3. Systems thinking models of a reinforcing causal loop (R4) of trade-off added-value and global food systems and national economy and a reinforcing loop of bio-fortification (R5) under *"modernising the farming process"*.

(Source: Authors' creation.)

As shown in Figure 4, climatic externalities on agricultural co-operatives – deep farming, agroecosystem, organic farming, vertical farming, or conventional food systems – may delay a reinforcing causal diagram of food systems. Less organic farming seems to raise GHG; rural capital and credit mechanisms could affect rural farmers' welfare in the agricultural economy and women's capabilities. Overall, "MFP" may affect macroeconomics, politics, and law.

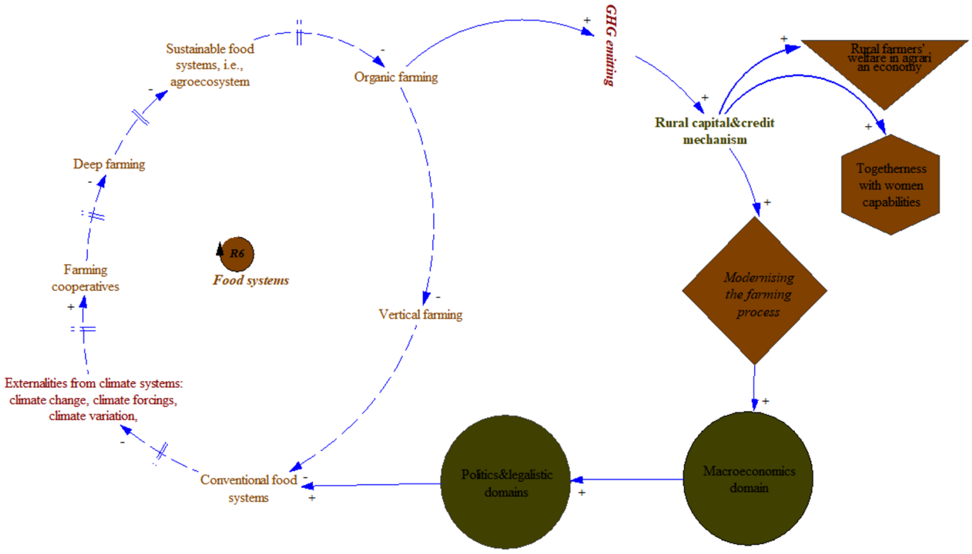

Fig. 4. Systems thinking models of *"modernising the farming process"*.

(Source: Authors' creation.)

This manuscript uses the "MFP" systems thinking approach to argue that increased food systems or access to world market opportunities for farmers through agricultural goods exports will improve farmers' average income and transform rural lives in the NWAR. Due to the link between input effort and outcome, economic incentives generally effect performance [42]; the same is true for "MFP". Family farmers are supposed to contribute to global food security but rarely receive government support [5].

2 Theory of the Peasant Economy, Along with Food Systems and Export

The article asks, 'what is out there [in the world of farmers in the NWAR] to obtain their particularistic knowledge, to a significant extent their universalistic ones', because 'epistemology' defines social reality. What is real about farmers' livelihoods? Since farmers' reality is manufactured, it promotes ontology. This study will investigate the process of obtaining farmers' reality knowledge.

Modern technologies such as fertiliser, seeds, water and soil conservation, manure application, and irrigation are used in family farm modernisation [10, 4]. "MFP" considers agricultural loans, farmers' organisations (co-operatives), training, and net capital stock (tractors, machinery, irrigated land, permanent crops, and animals) [11, 5].

The food systems theory also considers financial performance and employment rate (such as agriculture value added per worker and agricultural employment) [43, 44]. Environmental factors include water, soil, and land use (such as agricultural irrigation). In contrast, social issues include gender equity and inclusion, such as female agricultural labourers and fair trade producers. In comparison, export theory addresses product volume and value [11, 4].

Knowing the services and knowledge-based economic activities NWAR farmers conduct, "MFP" may help establish causation and constitutive validity. Thus, reorganising farmers or adopting new production methods [11] may improve micro food systems and national economic growth. In this way, NWAR farmers modernised, changing their land [10, 11, 45].

3 Methodology, Conceptual Frameworks, Data Analysis, and Empirical Model

This article should match the hypothetico-deductive process since it develops or obtains the NWAR theory of "MFP" [46, 47], which begins with an initial observation [46]. The statistical test consequences are drawn from this article's assumptions [47], backed by valid inference through deductive and non-deductive reasoning [47]. On one side, random effects modelling methodologies became preferred, believing that NWAR changes in food systems or export related to the claimed cause, "MFP", would influence the presumed effect. Besides its modelling methodologies of higher-level variables, [48] mentions its flexibility and generalizability.

The systems thinking approach fits policy analysis and its implications; as such, both approaches fall under the hypothetico-deductive method, allowing the inference to the best explanation of "MFP" by highlighting the essential predictive differences from the econometric models and the system dynamic approaches among NWAR farmers [47].

This article used cross-sectional time series data from 22 NWAR countries, 6 from NA and 16 from WA, for a 10-year time variable from 2011 to 2020.

This article purposefully used data from [3, 22, 37, 49, 50, 51]. Stata MP 17.0 statistics programme was used to analyse economic model data. Vensim PLE 7.3.5 was used for data analysis of systems thinking or conceptual frameworks and policy implications of system dynamics simulation. The simulation time step (DT) was 0.25, and the initial and final times were 0 and 50 years respectively.

Only the data set for the 'level of food systems' as stock utilised the best linear unbiased prediction, post-estimation, for random effects of this article's econometric models. 'Annual production' is its inflow auxiliary variable, and 'climate change', 'agricultural production area,' and 'technology innovation' are constants. Meanwhile, its outflow variable is 'annual household consumption' with 'population' and 'consumption per capita' as constants. Inflows are 'agricultural policy' while outflows are 'food supply'. Finally, Microsoft Excel was used to design the tables.

Using a random effects empirical model, this study tested whether "MFP" influences food systems or agricultural exports.

$$Y_{it} = \gamma_0 + \delta_0 X_{it} + \cdots + \delta_k X_{kt} + \mu_{it} + \varepsilon_{it} \quad (6)$$

The econometric model respectively becomes:

$$Foodsystems_{it} = \gamma_0 + \delta_0 MFP_{it} + \mu_{it} + \varepsilon_{it} \quad (7)$$

and

$$Export_{it} = \gamma_0 + \delta_0 MFP_{it} + \mu_{it} + \varepsilon_{it} \qquad (8)$$

In this study, i indexes the individuals or 22 NWAR countries; t indexes the period wave, as $t = 2011, 2014, \ldots, 2020$; $Foodsystems_{it}$ and $Export_{it}$ index continuous outcome variables; and MFP_{it} is a continuous predictor variable.

The slope coefficient of the presumed cause variable is δ_0 ; the between-entity error is μ_{it}; the within-entity error is ε_{it} , and the unknown intercept is γ_0 .

Table 2 defines the variables, dimensions, indicators, and theories.

Operationalisation of variables

Nature	***Variable***	***Definition***	***Dimension***	***Indicator***	***Theory***
Independent variable	MFP	encompasses means intended to use and reorganise in the farming production systems from downstream to upstream	net capital stock (tractors, machinery, irrigated land, land under permanent crops, livestock) worker training in AFF		(Bougma *et al*., 2021; Chayanov, 1996; FAO, 2020a)
			membership in farmers' organisation credit in AFF	co-operatives	
			water and soil conservation techniques	manure applied to soils and agriculture water managed and an area equipped for irrigation	
			modern technologies	fertiliser use and seeds	
Dependent variable	Food systems	is comprised of sub-systems, interacts with other key systems, encompasses various actors and their interlinked value-adding activities, as well as considering all relevant causal	economic (financial performance and employment rate)	agriculture value added per worker and employment in agriculture	(Béné, 2019; FAO, 2018; HLPE, 2019)

		variables of a problem to achieve systemic transformation			
			environment (water use and soil and land use)	agriculture water withdrawal of total renewable water and agriculture land of arable land	
			social (gender equity and inclusion)	Female employment in agriculture and predominant fair trade organisations and producers	
Dependent variable	Export	export of agricultural goods covers the trade for agricultural products and food products	Trade	volume and value of the goods	(Chayanov, 1996; FAO, 2020a)

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			worker training in AFF		
			membership in farmers' organisation	co-operatives	
			credit in AFF		
			water and soil conservation techniques	manure applied to soils and agriculture water managed and an area equipped for irrigation	

			modern technologies	fertiliser use and seeds	
Dependent variable	Food systems	is comprised of sub-systems, interacts with other key systems, encompasses various actors and their interlinked value-adding activities, as well as considering all relevant causal variables of a problem to achieve systemic transformation	economic (financial performance and employment rate)	agriculture value added per worker and employment in agriculture	(Béné, 2019; FAO, 2018; HLPE, 2019)
			environment (water use and soil and land use)	agriculture water withdrawal of total renewable water and agriculture land of arable land	
			social (gender equity and inclusion)	Female employment in agriculture and predominant fair trade organisations and producers	

Dependent variable	Export	export of agricultural goods covers the trade for agricultural products and food products	Trade	volume and value of the goods	(Chayanov, 1996; FAO, 2020a)

Source: [4, 10, 11, 12, 43, 44]

The core conceptual framework of operationalising variables tests questions 1 and 2 of this article, as presented in Figure 5 below.

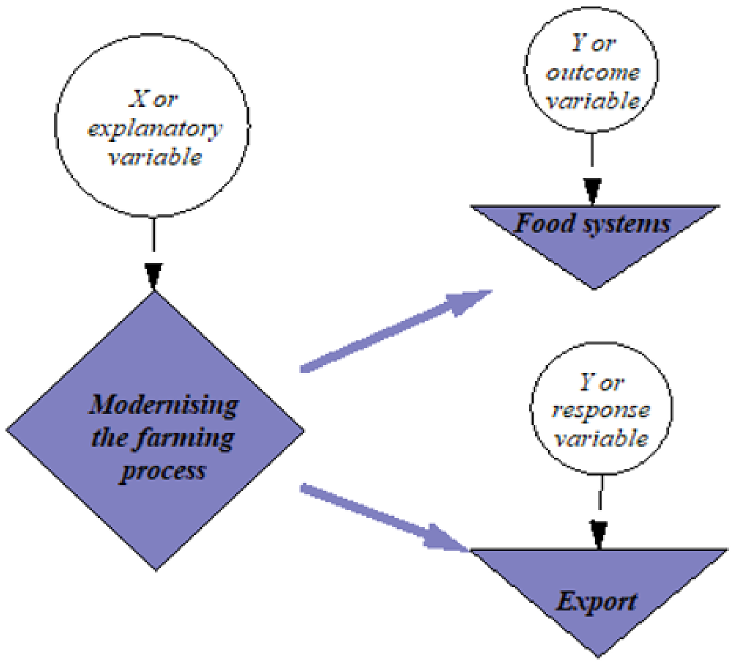

Fig. 5. Fundamental conceptual framework of operationalisation of variables

Source: Authors' creation.

Meanwhile, the conceptual framework model of the system dynamics seeks to answer qualitative question 3 of this article, as shown in Figure 6 below.

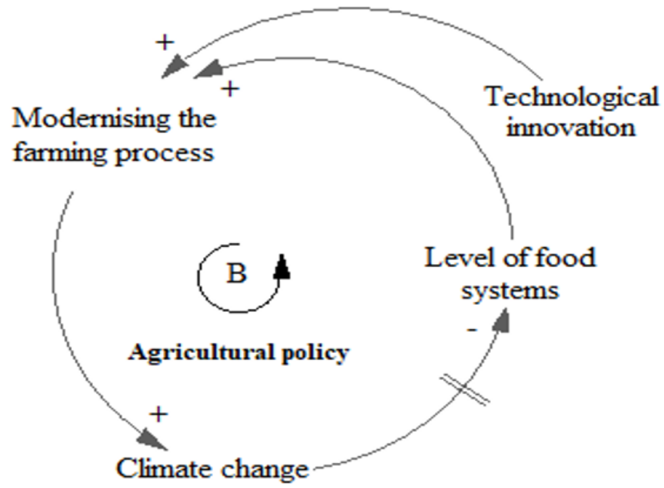

Fig. 6. System dynamics of agricultural policy. Source: Authors' creation

Indeed, a broad rise in "MFP" substance will likely be beneficial. Climate change externalities delay food systems. However, enhanced food systems or sub-systems with value-adding tend to modernise farmers and reshape the countryside in these places, balancing a policy in agriculture, forestry, and fishing as an umbrella.

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3.1 Analysis and empirical results

The analysis begins with NWAR agriculture policy distribution. Standardised policy aspects are shown in Table 3. Most crucially, the NA region increases farming production for market prospects, whereas the WA region increases farming to expand the food and agriculture sector. However, rising global agrarian protectionism denies market access to both regions. Upstream organisation, such as co-operative exports, is needed to sustain farmed output. Table 3 shows that the agriculture sector needs strong administrative and management skills and training to move from 'low-paid' to 'medium-paid'.

The box plot in Figure 7 shows the policy performance in the AFF sector.

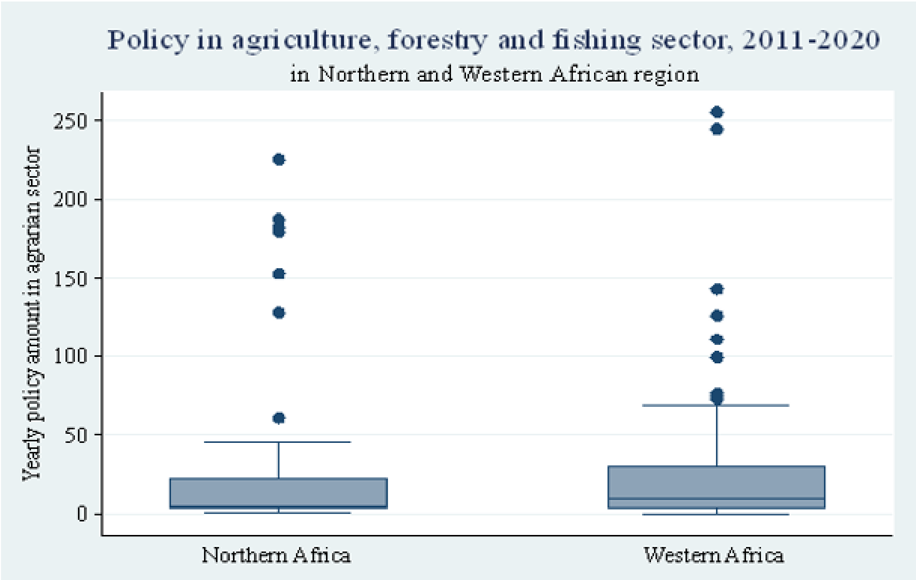


Fig. 7. Policy in agriculture, forestry, and fishing sector, 2011-2020, in the Northern and Western African regions. Source: Authors' analysis

Table 3. Analysis of agricultural policies in the Northern and Western Africa regions

Analysis of Agricultural Policies in the Northern and Western Africa regions			
Region	***Support***	***Constraint***	***Impact*** ***positive aspect***
Northern Africa	increase production of commodities (cereals, meat, dairy products, and fish)	prices of agricultural goods remain low slow demand growth for meat products due to regional variation preferences and disposal of income	market search prospects for agriculture and fish commodities at national, regional, and global levels
	livestock intensification		increased per capita consumption of staple foods (cereals and sugar) is expected to be flat as well as on cereals, roots, and tubers
		Constraint agricultural trade policy uncertainties rising protectionism at the global level import dependency on essential food commodities	***negative aspect***
		farming underwater issues	Low intake from animal sources

Western Africa	Expansion of the food and agricultural sector	dependency on donors' assistance	***positive aspect***
	boost mix farming of export commodities (cocoa, cotton, trees) with staple foods (maize, cowpeas)	not enough research and development in the agrarian sector	increased growth of production
		lack of robust administrative capacities for service delivery	decrease in food deprivation
	incentive policy (on farming production, minimum prices for farmers)	low investment associated with weak infrastructure and public investment for essential services	improved farming in arid areas
		lack of export or output incentives (relative prices: export crop)	enhancement of income and other development Indicators among smallholder farmers
		increase of structural inequalities, as women, the underprivileged	improvement of cash crop farming
		farmers are excluded from high value-added markets due to lack of resource accessibility or unequal distribution to productive assets: credit, marketing infrastructure	the increased social and environmental output resulting from mixed farming production of trees
			price ceiling at wholesale and retail levels
		poverty and food insecurity in rural areas remain high	extension of land rights for low-income female farmers
		the high price of (staple) food (maize) due to climatic repercussions	

	market denial or global protectionism in the agrarian sector	***negative aspect*** West African farmers' loss: 10-11 million cotton resulting from US subsidies and market restriction

Source: [52, 53, 54, 55, 60]

Figure 8 shows NWAR's inspection of AFF education or training.

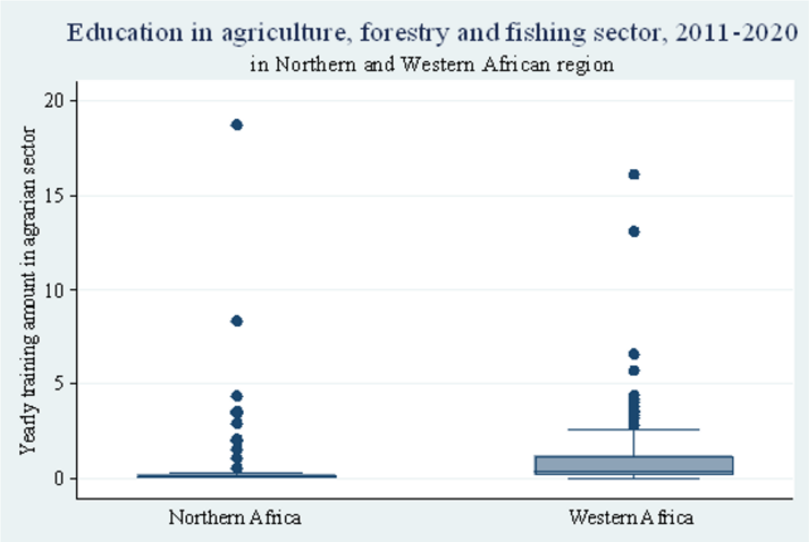


Fig. 8. Education in agriculture, forestry and fishing sector, 2011-2020, in the Northern and Western Africa regions. Source: Authors' analysis.

Figure 9 shows the proportion of NWAR agricultural co-operatives organising farmers upstream.

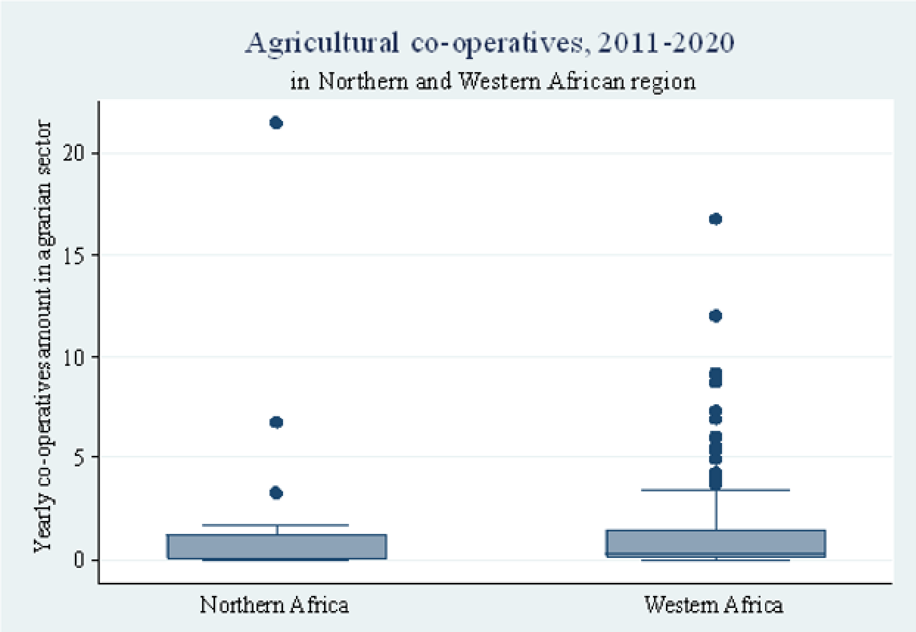


Fig. 9. Agricultural co-operatives, 2011-2020, in the Northern and Western African regions. Source: Authors' analysis

Thus, both econometric models have used the Hausman test to estimate the attributes that determine which model, between fixed and random effects, is acceptable [56], and its value test statistic did not reject the null hypothesis of a random effects model. Random effects can simulate a time-varying covariate, which may differ from the variables in this article due to NWAR changes in their effect on the dependent variable [48]. In addition, the Breusch-Pagan Lagrange multiplier test null hypothesis favoured random effects over ordinary least squares regression for both models because it determines which model is best [57, 58].

The econometric model of export as a function of "MFP", which has a serial correlation, failed to reject the null hypothesis. The model of food systems is as a function of "MFP". The Shapiro-Wilk test measured the normality distribution, but both econometric models are not normally distributed. Even though it was a fixed effects test, this study assessed for heteroscedasticity and rejected the null hypothesis for both econometric models. Next, Mundlak's formulation works when errors are heteroscedastic, or there is a correlation between groups. Each time-varying covariate accounting for a higher-level mean for the between effect is treated like any higher-level variable [48] in micros and macro models. Therefore, its value statistic failed to reject the null hypothesis for both econometrics models.

Because of heteroscedasticity in the export econometric model, timeseries random effects regression made standard errors more robust. In contrast, the food systems econometric model has heteroscedasticity and serial correlation, hence the random effects clustered the standard errors throughout this article to possibly rectify them, as presented in Table 4.

Table 4. Descriptive statistics of variables, 2011-2020

Variables	Unit	Mean	Maximum	Minimum
Modernising the farming process	degree level	2048456	12900000	60042.2
Food systems	degree level	2247.556	18689.3	433.9
Export in the agrarian sector	degree level	1053685	7090271	543.5

Note: Due to the average of dimensions, a unit of variables considers the level of degree of performance.
Source: Authors' analysis

The sample coefficient in this article indicates that both econometric models are far away from 0 as the F test statistics rejects the null hypothesis ($H_0: \delta_0 = 0$) at a 5% level of significance. Table 5 shows that the slope coefficient of MFP is different from 0 because of the alternative hypothesis ($H_1: \delta_0 \neq 0$) for both models.

Table 5. Random effects regression results, 2011-2020

Dependent variable	Food systems	Export of agricultural goods
Econometric models	Model 1	Model 2

Modernising the farming process in the region of Northern Africa	0.150**	0.478***
Modernising the farming process in the region of Western Africa	0.123*	0.195*

Notes: Significance levels: * for 5%; ** for 1%; and *** for 0.1%

Source: Authors' analysis.

In the NWAR, the chances of obtaining samples as extreme as $\delta_0=0.150$ and $\delta_0=0.123$ are respectively 0.005 and 0.026, less than 0.05. At 5% significance, the inference in this paper is that the value test statistic of "MFP" is associated with alimentary systems in both regions.

As a result, the predictor "MFP" has a highly significant influence on the outcome "food systems", as the NWAR expects the predicted value of "food systems" to grow by 15% and 12.3% degree level respectively for every additional degree level of "MFP". Hypothesis 1 is provisionally supported.

Additionally, if the null hypothesis is true ($\delta_0=0$), the chances in this study of obtaining extreme samples ($\delta_0=0.478$ and $\delta_0=0.195$) are 0.000 and 0.022, both below 0.05 for both locations. At a 5% significance level, the inference in this article is that the value test statistics of "MFP" are associated with exports in both regions.

For every degree level of "MFP", the predicted value of 'export' grows by 47.8% and 19.5% degree level on average, respectively, in the NWAR. Therefore, hypothesis 2 is provisionally supported. The real-time simulation of the agricultural policy model reveals that 'agricultural policy' has a slider related to the "MFP" in both regions. As the slider moves, the behaviour of "MFP" varies in response to the 'agricultural policy' in NWAR, as shown in Figure 10.

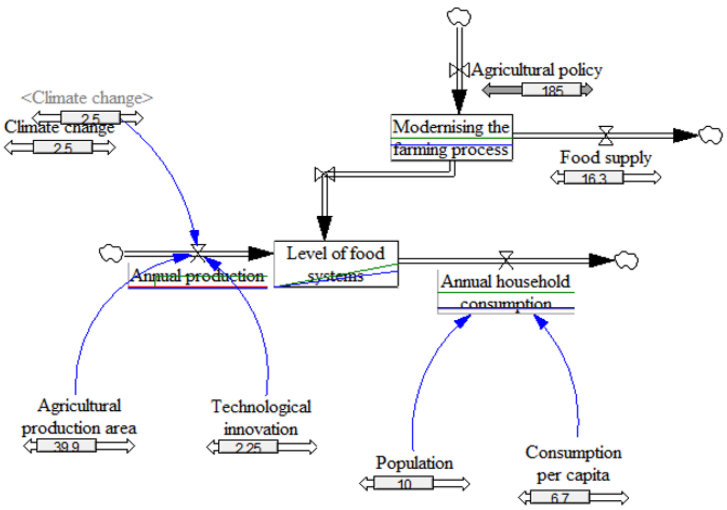
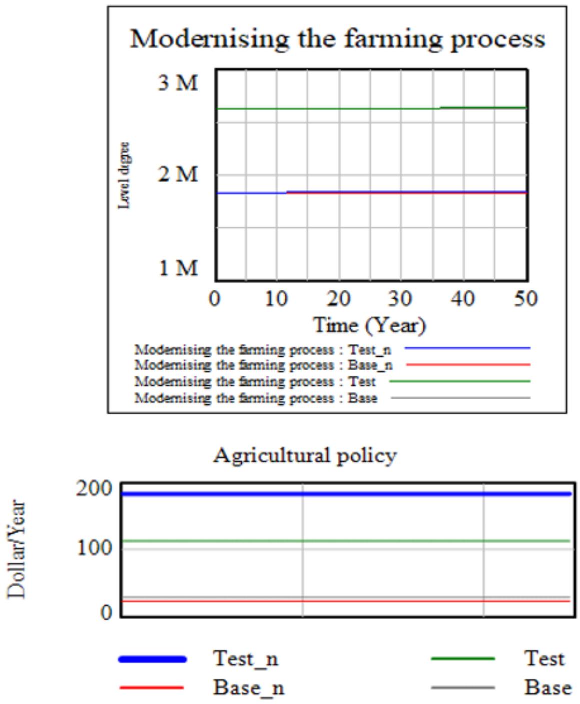


Fig. 10. Modelling behaviour of modernising the farming process in response to agricultural policy in Northern and Western Africa. Source: Authors' analysis.

Asymptotic behaviour is shown in Figure 11 as the stock of *"MFP"* approaches an equilibrium value of 3 million and 2 million degree levels in NWAR. Thus, the balancing feedback loop of 'agricultural policy' seems to dominate dynamic systems, leading the system to an equilibrium of approximately USD 100 million and $200 million per year, respectively, in these regions from almost the same base level of USD 20 million per year.



Notes: Base: model at the start in Northern Africa; Base_n: model at the start in Western Africa; Test: model at the end in Northern Africa; Test_n: model at the end in Western Africa

Fig. 11. Causes strip of "modernising the farming process" stock and "Agricultural policy" inflow in Northern and Western Africa.
Source: Authors' analysis.

4 Discussions

The paper demonstrates that:

a. NWAR's prevalence rate of 15% and 12.3% indicates a rise in food systems with each level of "MFP". Each "MFP" level boosts NWAR export value by 47.8% and 19.5%.
b. At a 5% significance level, "MFP" is a necessary and sufficient condition for boosting food systems and exports in these regions. However, agricultural policy may alter NWAR output. WA has lower agricultural exports (19.5% vs. 47.8% in NA) but similar food systems (12.3% vs. 15% in NA).

[59] The "poverty paradox" or "the plentiful (-supply-) paradox" may explain this (see Table 3 and agriculture policy dissemination introduction). WA has severe hunger (21.5, Table 1). Thus, to alleviate "moderate" hunger in the NA region (as 11.4, Table 1), their strategies boost food and agricultural productivity. Their initiatives attempt to increase commodities output for domestic, regional, or international markets.

c. The policy analysis in the article indicates that NA agricultural policy attempts to boost domestic, regional, and global commodity market prospects. Technology exports are crucial to shifting agricultural policy from farming to high-value commercial services. This article suggests that Western African agriculture policy may need a sophisticated method to gain market access.
d. The dynamic system simulation for the article shows that "MFP" behaviour and 'agricultural policy' differ in both regions. As "MFP" approaches equilibrium, the balanced feedback loop of 'agricultural policy' dominates dynamic systems, rendering it into an insufficient condition.

Agricultural policies' positive and negative effects in these locations are shown in Table 3. To address these findings, governments should:

a. Implement a gender-sensitive approach in farmers' professional co-operatives, integrating gender into the farming process. Import replacement of critical food items by NA should affect agrarian industrial relations.
b. Execute innovative trade, technology, service, and infrastructure construction policies to obtain fair trade accreditation, including high-standard farmlands and field construction. This strategy can affect product types and sales.
c. Consider innovative structural policies, such as encouraging agricultural technology, infrastructure, upgrading, or equipment in WA, which can impact farm scale, product specialisation, value-adding, off-farm income, FDI, and manufacturing in the agrarian sector.
d. Enhance innovative modern economic incentives policies (as adjusting the concise target of the agricultural subsidy system, increasing direct subsidy intensity, providing agricultural service support, introducing an innovative premium subsidy system in agricultural insurance reform, or accelerating farmer income support policy) combined with agriculture investment policy (as improving the system of modern rural financing diversified, and increasing public financial and private and social investment entities), agriculture price support (as with the system of minimum purchase price policy for grain and modern broader inputs using related legalisation of agricultural price support), and innovative agricultural insurance policy (as establishing an agricultural system of risk dispersion, introducing social resources in the social capital platforms, or creating a succinct agricultural insurance system) from upgrading/value-adding upstream farming production process (farming/financial systems, inputs and services, and transport and water infrastructures systems onset for farming and domestic usage) to farming output level.
e. Implement appropriate technology, research, and development policies to enhance innovation and application in modern agricultural science as well as to enhance knowledge and training for stakeholders in both regions.

The qualitative study question and these areas' particularities suggest that agricultural extension policy should embrace those policies as an industrialisation strategy in their countryside since 'agricultural policy' is required but not sufficient. 'Agricultural policy' is required and sufficient in both regions because of "MFP" and food systems and exports. NWAR uses "MFP" based on the employed theory ([4, 10, 11, 40, 43]) and family farming innovation theory [5]. "MFP" is required in these locations. Still, it is disputed in terms of (i) technology application for sustained productivity and agricultural research, extension, and advisory services, and (ii) local wisdom (of farmers/family farming) for individual/organisational capability development.

5 Conclusion

The inference from this article is that what is out there in the world of farmers in the NWAR is that every additional degree of "MFP" increases the level of food systems by 15% and 12.3%, respectively, in these regions.

Similarly, every additional degree of "MFP" increases export by 47.8% and 19.5%, respectively, which enabled this article to obtain particularistic knowledge of these regions. Thus, hypotheses 1 and 2 are provisionally supported. "MFP" is a sufficient and necessary condition at a 5% significance level to influence these regions' food systems and exports.

Furthermore, knowledge of these regions can be accessed through the comprehension of their respective policies as this article has shown that the behaviour of "MFP" (as at approximately the 3 million and 2 million degree level) varies in response to the 'agricultural policy' (as USD 100 million and 200 million) respectively in NWAR at equilibrium, where the behaviour is asymptotic of "MFP"; thus, the balancing feedback loop of 'agricultural policy' is a necessary condition but not a sufficient one in both regions, even though it is associated to "MFP".

To a large extent, universalistic knowledge is the agricultural extension policy, much more preferably its extension in modern agrarian science, agriculture digitalisation, and systematic, precise, and regular farm information as well as data, high-end service, and high-end technological innovation and application policy, jointly with a farmer income support policy that intends to improve the constituent, as the method of process and continuous update/change of related innovative modern inputs, (in response to the research question) in the light of the suggested policies in these regions, which is the implication policy for "MFP" to fulfil this article's purpose.

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