Lisbon School of Economics & Management
Universidade de Lisboa

MASTER

INNOVATION AND RESEARCH FOR SUSTAINABILITY

MASTER´S FINAL WORK

DISSERTATION

FEMALE AGRICULTURAL LABOUR, ASSETS, AND HOUSEHOLD WELL-BEING AMONG TUNISIAN SMALLHOLDERS

AVERY ELIZABETH KEENAN BOTA

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SUPERVISION:
PROFESSOR IDALINA MARIA DIAS SARDINHA
PROFESSOR ADAM JOHN STANDRING

GLOSSARY

ATI – Agricultural Technology Index.

BNI – Basic Needs Index.

DFID – Department for International Development.

EU – European Union.

FCS – Food Consumption Score.

FLDR – Female Labour Density Ratio.

GDP – Gross Domestic Product.

HH – Household.

HMMR – Hierarchical Moderated Multiple Regression.

LTSI – Land Tenure Security Index.

MENA – Middle East and North Africa.

PQoL – Perceived Quality of Life.

SLF – Sustainable Livelihoods Framework

SLF 21st Century – Sustainable Livelihoods Framework for the 21st Century. Reformulated framework by Natarajan et al. (2022).

SPSS – Statistical Package for the Social Sciences.

TND – Tunisian Dinars.

VIF – Variance Inflation Factor.

WFP – World Food Programme.

ABSTRACT

Agricultural feminization—the increasing reliance on female workers in farm production—presents a fundamental wellbeing paradox in resource-constrained smallholder systems. When male out-migration creates labour deficits, households may substitute lower-cost female workers, potentially achieving economic gains through wage cost reduction though this often coincides with intensified workloads for women. This study examines how female labour density relates to multi-dimensional household wellbeing among Tunisian olive-cultivating smallholders (N = 62), testing whether land tenure security and agricultural technology moderate these relationships. Using hierarchical moderated multiple regression with data from 2022-2023, a period characterized by drought, political instability, and macroeconomic downturn, the analysis assesses three wellbeing dimensions: Food Consumption Score (nutritional security), Basic Needs Index (economic capacity), and Perceived Quality of Life (subjective wellbeing). Results show that female labour density significantly predicts improved subjective wellbeing ($\beta = 0.31$, $p = .048$), supporting the hypothesis that feminization enables household-level adaptation through cost reduction. Despite this relationship, neither land tenure security nor agricultural technology moderates labour-wellbeing relationships in generalizable patterns. Sensitivity analyses reveal that external hired female labour shows positive associations with wellbeing ($\beta = 0.25$, $p = .092$) and exhibits tenure-based conditional effects for economic outcomes ($\beta = 0.35$, $p = .015$), while household-member feminization demonstrates null effects across all dimensions. Regional stratification exposes spatial heterogeneity wherein coastal households with superior infrastructure derive tenure-conditioned benefits from feminization, while interior households show no such moderation. This constitutes the first application of 'A Sustainable Livelihoods Framework for the 21st Century' (Natarajan et al., 2022) to North African agricultural feminization, revealing that identical labour strategies produce divergent wellbeing outcomes depending on labour source, regional infrastructure context, and investment security rather than merely formal ownership documentation.

Keywords: Agricultural feminization; Household wellbeing; Sustainable livelihoods.

JEL Codes: Q12; Q15; I31, J43; J16.

RESUMO

A feminização da agricultura — a crescente dependência das trabalhadoras na produção agrícola — apresenta um paradoxo fundamental em termos de bem-estar nos sistemas de pequenos agricultores com recursos limitados. Quando a migração masculina cria déficits de mão de obra, as famílias podem substituir trabalhadores por trabalhadoras de menor custo, potencialmente obtendo ganhos económicos através da redução dos custos salariais, embora isso coincida com o aumento da carga de trabalho para as mulheres. Este estudo examina como a densidade da mão de obra feminina se relaciona com o bem-estar multidimensional de pequenos agricultores tunisinos que cultivam azeitonas (n = 62), testando se a segurança da posse da terra e a tecnologia agrícola moderam essas relações. Utilizando regressão múltipla moderada hierárquica com dados de 2022-2023, período caracterizado por seca, instabilidade política e recessão macroeconómica, a análise avalia Pontuação de Consumo Alimentar, Índice de Necessidades Básicas e Qualidade de Vida Percebida. Os resultados demonstram que a densidade da mão de obra feminina prevê significativamente uma melhoria do bem-estar subjetivo ($\beta = 0.31$, $p = 0.048$), apoiando a hipótese de adaptação familiar através da redução de custos. Contudo, nem a posse da terra nem a tecnologia agrícola moderam essas relações em padrões generalizáveis. Análises de sensibilidade revelam que a mão de obra feminina contratada apresenta associações positivas com o bem-estar ($\beta = 0.25$, $p = .092$) e efeitos condicionais baseados na posse da terra ($\beta = 0.35$, $p = .015$), enquanto a feminização dos membros do agregado demonstra efeitos nulos. A estratificação regional expõe heterogeneidade espacial: famílias costeiras com infraestruturas superiores obtêm benefícios condicionados à posse da terra, enquanto famílias do interior não. Esta constitui a primeira aplicação do 'A Sustainable Livelihoods Framework for the 21st Century' (Natarajan et al., 2022) à feminização agrícola no Norte de África, revelando que estratégias idênticas produzem resultados divergentes dependendo da fonte de trabalho, infraestruturas regionais e segurança do investimento.

Keywords: Feminilização da agricultura; Bem-estar familiar; Meios de subsistência sustentáveis.

Códigos JEL: Q12; Q15; Q18; I31, J43; J16.

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AI DISCLOSURE

This internship report adheres completely to the academic integrity policies and guidelines established by the university. To maintain full openness regarding my research and writing process, I wish to declare the following uses of artificial intelligence technology:

- A conversational AI platform was consulted exclusively during the preliminary planning phase to assist with structural organization and initial concept development. All subsequent writing, analytical interpretation, synthesis of information, and critical evaluation are entirely my own intellectual contribution.
- An automated grammar and language refinement tool was applied to enhance textual clarity and ensure effective communication, while carefully preserving my original arguments and viewpoints throughout the document.
- A computer-assisted rewording application was utilized to reformulate certain quotations from published works included in the literature review, though all referenced scholars have been properly credited for their original contributions and research findings.

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Avery Elizabeth Keenan Bota, 24/01/2026

1.0 INTRODUCTION

Agricultural feminization, defined as the increasing participation of women in farm labour, presents a fundamental wellbeing paradox that exposes tensions between household-level economic rationality and individual-level distributional justice. When resource-constrained smallholders respond to labour scarcity by substituting female workers for male labour, wellbeing implications depend critically on the analytical scale: households may achieve economic gains through wage cost reduction, though this can coincide with intensified workloads for women whose experiences may not be fully captured within aggregate household accounting. This scalar tension reflects broader debates regarding the household as analytical unit—whether it functions as a unified cooperative entity pursuing collective wellbeing maximization, or as contested terrain wherein asymmetric power relations enable some members to capture benefits whilst externalizing costs onto others.

The feminization phenomenon thus illuminates foundational questions about livelihood adaptation under constraint: do labour reconfigurations represent strategic innovations that expand household capabilities, or erosive responses that sacrifice long-term sustainability for short-term survival? The answer hinges on structural conditions extending beyond individual household agency—institutional frameworks governing labour protections, capital asset endowments enabling productive investment, and power relations determining whose priorities shape resource allocation and whose wellbeing defines success. Understanding whether feminized labour strategies constitute genuinely transformative pathways or merely redistribute deprivation across gender lines requires examining how these structural factors condition the relationship between women's agricultural participation and multidimensional household outcomes.

This investigation examines these dynamics within Tunisia's rural interior, where olive-producing smallholders navigate changing conditions. As male household members increasingly migrate coastward seeking diversified income (Najjar & Baruah, 2024), substantial gender wage gaps—women earning 15-25 Tunisian dinars per day against men's 22-80 dinars (Weber et al., 2020; Bajec, 2020)—incentivize two feminization pathways: intensifying unpaid agricultural work by female household members or recruiting external female workers at reduced cost. Three-quarters of female agricultural workers operate without formal employment contracts (Bajec, 2020), limiting access to

credit institutions, professional development, and governmental support services (Najjar & Baruah, 2024).

Tunisia's agricultural sector transformation reflects neoliberal restructuring that fundamentally favoured large-scale, export-oriented production (Poletti, 2025). These reforms were deepened through the 1995 Euro-Mediterranean Association Agreement, positioning Tunisia within unequal exchange patterns (El Nour et al., 2024). Political instability following the 2011 revolution compounded these economic pressures: nine governments cycled through power between 2011 and 2021 (Chomiak, 2021), whilst President Saied's 2021 parliamentary suspension further constrained state capacity (Ash, 2023). Macroeconomic conditions deteriorated as sovereign debt reached 85% of GDP and economic growth collapsed from 4.6% annually (2001-2010) to 1.4% (2011-2019) (Yilmaz et al., 2025). Environmental stress intensified these pressures, with 2022 marking the driest year since 1950, substantially affecting rainfed olive cultivation (Poletti, 2025; Frija et al., 2021).

Olive cultivation provides primary livelihood support for 65% of Tunisia's farmers (Weber et al., 2019), dominated by smallholder operations under 10 hectares (Gharbi et al., 2025). Labour-intensive manual olive picking concentrates demand within narrow harvest timeframes, addressed through family and temporary labour (Weber et al., 2020)—particularly necessary when male members engage in off-farm employment or migration (Najjar & Baruah, 2024). Smallholders face significant market access constraints: many lack formal land titles required for institutional credit, forcing reliance on informal intermediaries who extract up to 30% of workers' wages (Bajec, 2020; Fetoui et al., 2020; Najjar & Baruah, 2024).

These constraints are shaped by Tunisia's pronounced coast-interior divide. Coastal zones benefit from infrastructure connectivity, extension services, formal credit, and diversified economic opportunities (Bassem, 2025; Bousnina, 2023; Abbassi & Benhamed, 2025), whilst interior regions face vastly different conditions despite holding substantial productive resources (Knaepen, 2021). Male outmigration from Northwest and Center-West governorates toward coastal regions (Bousnina, 2023; Mhadhbi & Napoléone, 2022) forces households to shift agricultural responsibilities to female members despite their constrained access to physical capital, social capital, and market connections (Najjar & Baruah, 2024; Baada & Najjar, 2020).

The analytical architecture derives from the Sustainable Livelihoods Framework for the 21st Century (Natarajan et al., 2022), which addresses foundational critiques by rejecting methodological individualism and foregrounding structural determinants of livelihood possibilities. The reformulated framework consolidates the original five-capital typology into three integrated dimensions: *Assets* (financial and physical capital), *Relational Power* (how gender, class, ethnicity, and caste structure differential access), and *Climate and Environmental Context/Relations* (positioning ecological dynamics as constitutive rather than contextual). Livelihood outcomes emerge through interaction of *Transforming Structures and Processes* (political-economic formations across spatial scales) with *Livelihoods in Flux* (adaptive household responses under constraint).

Empirical applications illuminate gendered agricultural transformation. Southeast Asian rice systems show male outmigration creating cascading capital deficits disproportionately affecting women through gendered task allocation, forcing erosive responses including land abandonment as women lack equivalent access to resources (Delina et al., 2024). Ethiopian studies establish that physical capital endowments determine which climate adaptation practices become accessible, with male-headed households demonstrating greater adoption capacity (Adamseged & Kebede, 2023). Grey literature illustrates how infrastructure inadequacy compels intensified unpaid reproductive labour, constraining women's participation in income-generating work, education, and rest (Sturridge, 2024).

Tunisian research reveals complex labour-wellbeing relationships. In Central Tunisia, over 40% of women in farming households experience food insecurity, whilst those securing off-farm employment exhibit significantly reduced food insecurity risks (Gaillard et al., 2022). In Sidi Bouzid, women have adapted livelihood diversification, generating revenue crucial for water, healthcare, and education costs (Mazhoud et al., 2025). Ethnographic research shows female agricultural workers take on contested labour—essential for production but undervalued and precarious—with access to employment providing indirect access to resources like water, though through exploitative arrangements (Djerbi, 2024).

International research establishes land ownership and tenure security as critical conditioning factors. Ownership of productive assets and resource control constitute primary factors shaping women's productivity, empowerment, and capacity to improve

household nutritional outcomes (Njuki et al., 2022). Formal land titles and protection from expropriation substantially improve women's empowerment and household bargaining power (Han et al., 2019). However, land access alone proves insufficient where complementary resources and decision-making authority remain constrained: in rural Bangladesh, land access did not translate into women's individual income despite increasing aggregate household income, due to limited decision-making power and restricted involvement in income-generating activities (Sultana et al., 2024).

Technology studies document varied effects. In Tunisia, adoption of agricultural innovations correlated with production improvements, income increases, and workload reductions (Najjar & Baruah, 2024). Conversely, mechanization and intensive input adoption in Northwest Tunisia displaced farm labourers without creating alternative employment, intensifying poverty and accelerating rural-urban migration (Mhadhbi & Napoléone, 2022). International research establishes that irrigation systems and motorised equipment influence food security whilst reducing manual water hauling burdens disproportionately assigned to women (Ongachi & Belinder, 2025; Fischer et al., 2022; Anand et al., 2025).

Despite extensive scholarship, knowledge gaps persist. Prior investigations adopted individual-level frameworks, overlooking collective household decision-making under constraint (Gaillard et al., 2022; Mazhoud et al., 2025). Prevailing approaches emphasize singular wellbeing dimensions, obscuring divergent responses across nutritional, economic, and subjective domains. Although the Sustainable Livelihoods Framework for the 21st Century has illuminated gendered labour dynamics across Indonesian, Philippine, and Ethiopian contexts (Delina et al., 2024; Adamseged & Kebede, 2023), its application to North African systems remains absent.

This investigation advances understanding through three innovations. Analytically, it assesses how female labour intensity—women's proportional representation within total farm workforce—shapes household-level wellbeing trajectories. Methodologically, it implements tripartite assessment encompassing dietary adequacy (Food Consumption Score), economic provisioning capacity (Basic Needs Index), and subjective wellbeing (Perceived Quality of Life), enabling detection of domain-specific trade-offs. Theoretically, it constitutes the first application of the Sustainable Livelihoods Framework for the 21st Century to North African agricultural feminization, testing

whether secure land tenure and agricultural technology condition feminized labour effectiveness as a wellbeing strategy.

Three hypotheses structure the investigation. First, feminized labour intensity positively associates with household wellbeing through cost reduction under resource scarcity, acknowledging that although feminization can operate within exploitative institutional arrangements, cost reduction may yield measurable household-level economic gains. Second, land tenure conditionally shapes relationships: households possessing both formal ownership rights and freedom from investment impediments should show enhanced capacity to channel feminized labour toward productivity improvements; tenure insecurity should prevent productive asset conversion. Third, agricultural technology access—irrigation infrastructure, mechanized cultivation, transport capacity—should reduce temporal constraints and physical depletion, permitting women's contributions to generate enhanced output rather than merely maintaining subsistence.

Empirical investigation analyzes primary household data from the SustInAfrica consortium: 62 olive-producing smallholder operations across Beja (interior sub-humid, n=31), Sousse (coastal semi-arid, n=20), and Monastir (peri-coastal, n=10). Data acquisition occurred June 2022-February 2023, capturing adaptations under drought, political transformation, and macroeconomic deterioration. Hierarchical Moderated Multiple Regression tests whether capital assets condition labour-wellbeing relationships, with controls for household demographics, education, farm size, generational structure, and geography.

The thesis comprises four chapters following this introduction. Chapter 2 develops the Literature Review: theoretical framework evolution, Tunisia's olive sector structure, neoliberal transformation and outmigration, agricultural feminization in Tunisia and MENA, feminized labour and wellbeing relationships, and literature synthesis specifying knowledge gaps. Chapter 3 details Methodology: research design, study area and sampling, data collection, variable operationalization, analytical strategy, and ethical considerations. Chapter 4 reports Results: descriptive statistics, hierarchical regression estimates, and sensitivity analyses. Chapter 5 synthesizes findings, suggests policy implications, acknowledges limitations, and identifies future research directions.

1.0 LITERATURE REVIEW

This chapter establishes theoretical and empirical foundations for examining feminized agricultural labour and household wellbeing in Tunisia's olive sector. While referencing the theoretical framework and its evolution since inception in 1992, the review draws on peer-reviewed articles and grey literature from international development organizations published between 2019 and 2025.

2.1 Theoretical Framework and Applications

The Sustainable Livelihoods Framework (SLF) originated with Chambers and Conway (1992), defining a livelihood as *Capabilities, Assets*, and *Activities* required for a means of living. A sustainable livelihood must absorb and recover from shocks, maintain or enhance its resource base and capabilities, while ensuring livelihood opportunities remain available for subsequent generations. Scoones (1998) transformed this into an analytical framework, later standardized in 1999 by the Department for International Development (Carney, 1999) with factors including: *Vulnerability Context, Livelihood Assets* (five capitals), *Transforming Structures and Processes, Livelihood Strategies*, and *Livelihood Outcomes* (Figure 1).

Despite widespread application, the framework has been subject to substantive critiques. Arku and Arku (2011) contended that it lacked specificity in delineating which Activities constitute livelihood means and risked overlooking non-market activities, including women's reproductive labour and domestic work, thereby potentially producing gender-insensitive analyses.

Natarajan et al. (2022) offered a substantial critique and reformulation. They identified critical structural limitations, arguing the original approach depoliticized poverty by treating it as a technical rather than political issue, obscuring power dynamics and structural inequalities. Their critique highlighted the framework's methodological localism—its focus on bounded households and villages—which failed to account for how livelihoods are increasingly delocalized through migration, remittances, and global market integration. They further contended its ahistorical perspective neglected long-term processes that fundamentally shaped current asset distributions. Additionally, by centring the five capitals, the framework tacitly accepted capitalist relations as given, and despite acknowledging natural capital, inadequately addressed the structural and relational nature of global environmental changes.

To address these limitations, Natarajan et al. (2022) reformulated the approach in 'A Sustainable Livelihoods Framework for the 21st Century' to explicitly politicize structural forces, incorporate multi-scalar geographic analysis, acknowledge temporal and historical dynamics, and foreground the constitutive role of environmental change. The reformulation reorganizes the original five capitals into three nested pentagons: *Assets* (financial and physical capital), *Relational Power* (articulating how gender, class, ethnicity, and caste structure differential access), and *Climate and Environmental Context/Relations*. *Livelihoods in Flux* replaces *Livelihood Strategies* to emphasize contingency and ongoing transformation over static planning.

Researchers have utilized this modified framework to examine gendered labour dynamics across diverse contexts. Delina et al. (2024) examined indigenous rice farming in Indonesia and the Philippines, revealing how youth outmigration driven by economic opportunities creates cascading capital dynamics across multi-sited households. This exodus compounds existing gender inequalities, as remaining farmers, often women, assume expanded agricultural responsibilities while experiencing eroded social capital through weakened labour networks and diminished human capital as local agricultural knowledge is lost. Despite remittance flows linking spatially dispersed families, capital deficits result in increased reliance on hired labour and rice field abandonment.

Adamseged and Kebede (2023) analyzed adaptation methods in Northern Ethiopian Highlands, demonstrating how *Relational Power* structures differential access to climate adaptation strategies. *Assets*—particularly physical capital such as farm size and productive inputs—intersect with gender to shape accessible practices, with tree growing to be more likely in male-headed households due to larger landholdings and asset bases.

A working paper by the Humanitarian Policy Group (Sturridge, 2024) referenced the SLF 21st Century to identify unpaid care work as a meso-level structural barrier, demonstrating how the *Politics of Influence and Access* operates through gendered social obligations that systematically constrain women's participation in livelihood opportunities—revealing how aid systems treating households as unified units fail to recognize intra-household power relations and care burdens as structural drivers of exclusion.

2.2 Structure of the Tunisian Olive Oil Sector

Olive cultivation constitutes an important economic component for Tunisia's rural interior, providing primary livelihood support for 65% of farmers (Weber et al., 2019). Smallholder operations of less than 10 hectares dominate this landscape, serving as a critical foundation for both economic activity and cultural continuity (Gharbi et al., 2025). The labour-intensive nature of manual olive picking concentrates demand within narrow harvest timeframes, which households address through family and temporary labour (Weber et al., 2020)—a strategy particularly necessary when male members engage in off-farm employment or out-migration (Najjar & Baruah, 2024; Najjar et al., 2018).

Irrespective of their economic importance, smallholders face significant market access constraints. Many lack formal land titles required for institutional credit, forcing reliance on informal intermediaries who extract up to 30% of workers' daily wages (Bajec, 2020; Fetoui et al., 2020; Najjar & Baruah, 2024). These constraints are further shaped by Tunisia's pronounced coast-interior development divide. While coastal zones benefit from infrastructure connectivity—proximity to processing facilities, input suppliers, and export ports—alongside access to extension services, formal credit, and diversified economic opportunities (Bassem, 2025; Bousnina, 2023; Abbassi & Benhamed, 2025), interior regions operate in entirely distinct circumstances. Despite holding 50% of Tunisia's oil, gas and water resources, 70% of wheat production, and 50% of olive oil and fruit production, inland provinces remain structurally disadvantaged (Knaepen, 2021).

2.3 Neoliberal Transformation and Male Outmigration in Tunisia

Tunisia's agricultural sector transformation reflects almost six decades of neoliberal restructuring that fundamentally reconfigured production systems and household livelihoods. Economic liberalization instituted an agricultural regime favoring large-scale, export-oriented production (Poletti, 2025), deepened through the 1995 Euro-Mediterranean Association Agreement that positioned Tunisia within unequal exchange patterns—exporting low-value crude olive oil whilst importing agricultural inputs (El Nour et al., 2024). This export-dependent model generated critical vulnerabilities: import reliance reached 50-70% of cereal requirements between 2000 and 2017 (Knaepen, 2021), whilst intensified production consumed approximately 80% of national water despite severe scarcity (Knaepen, 2021).

Political instability following the 2011 revolution compounded these economic pressures. Nine governments cycled through power between 2011 and 2021, undermining policy consistency (Chomiak, 2021), while President Saied's 2021 suspension of parliament further constrained state capacity for agricultural interventions (Ash, 2023). Deteriorating macroeconomic conditions accompanied these transitions: sovereign debt reached 85% of GDP by 2024, whilst economic growth collapsed from 4.6% annually (2001-2010) to 1.4% (2011-2019) (Yilmaz et al., 2023), manifesting through reduced public sector hiring and diminished agricultural input subsidies (Çuhadar et al., 2025; Knaepen, 2021).

Environmental stress intensified these pressures. The driest year since 1950 occurred in 2022, causing major reservoirs to drop below 20% capacity and substantially affecting the rainfed olive cultivation upon which smallholders depend (Poletti, 2025; Frija et al., 2021).

These converging structural and environmental pressures precipitated notable male outmigration from rural Tunisia, particularly from Northwest and Center-West governorates toward Tunis and eastern coastal regions offering infrastructure and diversified economic opportunities (Bousnina, 2023; Mhadhbi & Napoléone, 2022; Najjar & Baruah, 2024). This spatial reallocation reflects the persistent coast-interior divide, as interior regions lose productive working-age men without equivalent infrastructure investment (Abbassi & Benhamed, 2025; Najjar & Baruah, 2024). For agricultural systems dependent on male workers for mechanized operations and market negotiations, this exodus forces households to either modify productive activities or shift agricultural responsibilities to female members despite their constrained access to physical capital, social capital, and market connections (Najjar & Baruah, 2024; Baada & Najjar, 2020).

Within the SLF 21st Century framework, neoliberal transformation and out-migration in Tunisia represent interconnected dynamics across *Transforming Structures and Processes*—structural adjustment policies, labour market liberalization, reduced state support—that interact with *Climate and Environmental Context/Relations*, putting pressure on household *Assets* (financial and physical capital), *Relational Power* (as gender, class, and regional hierarchies structure differential access to land tenure and technology), and social-institutional networks. Male out-migration emerges as a

Livelihoods in Flux response, generating financial capital through remittances while depleting human capital and concentrating agricultural labour on women who lack formal control over land and resources, thereby establishing conditions for agricultural feminization without corresponding empowerment—a dynamic that manifests differently across interior versus coastal regions.

2.4 Agricultural Feminization in Tunisia and MENA

The Middle East and North Africa (MENA) region presents a distinctive paradox wherein substantial improvements in female educational attainment have not translated into commensurate economic participation (Çuhadar et al., 2025; Baliamoune, 2024). Regional Female Labour Force Participation remained at approximately 20% in 2019, compared to a global average of 48% (Moghadam, 2020), with 70% of Tunisian women over age 15 not participating in the labour force in 2024 (Çuhadar et al., 2025). This reflects complex interactions between institutional frameworks and sociocultural contexts, as traditional gender norms support a male breadwinner model (Lassassi and Tansel, 2020), with marriage by the median age reducing women's probability of market work by 30% in Tunisia (Assaad et al., 2020).

Economic contraction has further marginalized women, as austerity measures pushed 54% of women in Northern Africa and Western Asia into informal economy positions (UN, 2025). In Tunisia's agricultural sector specifically, only 33% of women workers are covered by social security (Bajec, 2020), while wage differentials compound these structural disadvantages. Women agricultural workers typically earn 15-25 Tunisian dinars per day compared to male wages of 22-80 dinars (Weber et al., 2019; Bajec, 2020), differentials rooted in norms constructing women's agricultural work as supplementary income (Mazhoud et al., 2025). Informal intermediaries coordinate job placement and transportation while extracting up to 30% of daily wages, a practice that particularly disadvantages rural women who lack direct networks with farm owners (Bajec, 2020).

The absence of enforced minimum wages, mandatory contracts, or workplace protections in Tunisia's agricultural sector (Bajec, 2020; Weber et al., 2020) generates pronounced gender inequities. Men access social protection at four times women's rate, leaving two-thirds of female agricultural workers outside social security, healthcare, and safety systems. Beyond immediate protections, the lack of written contracts constrains

women's ability to document farmer status required for formal credit, extension services, and cooperative membership (Bajec, 2020).

Taken through the SLF 21st Century perspective, these patterns represent *Relational Power* dynamics structured by gender, operating through *Transforming Structures and Processes* that systematically create differential outcomes for women. Patriarchal norms and institutional frameworks create conditions where women face barriers in converting educational attainment into Assets through formal employment, channelling them instead into informal agricultural labour with limited economic returns and social protections.

2.5 Feminized Agricultural Labour, Wellbeing and Moderating Factors

2.5.1 Female Agricultural Labour Participation and Wellbeing

Tunisian research examining women's agricultural engagement reveals complex relationships between labour intensification and household wellbeing. In Central Tunisia, over 40% of women in farming households experience food insecurity, whilst those securing off-farm employment exhibit reduced food insecurity risks alongside higher educational attainment (Gaillard et al., 2022). Further, male outmigration—a primary driver of feminization—can increase aggregate household income through remittances (Baada & Najjar, 2020), potentially offsetting individual-level vulnerabilities. In Sidi Bouzid governorate, women demonstrate adaptive capacity through livelihood diversification, generating revenue crucial for water, healthcare, and education costs, whilst expanding involvement in livestock rearing supports household adaptation (Mazhoud et al., 2025).

Ethnographic research reveals the daily realities women face in agricultural work. Female agricultural workers take on contested labour, essential for production but undervalued and increasingly precarious due to ecological and economic stress (Djerbi, 2024). Access to employment provides indirect access to resources—particularly water from wells—otherwise unavailable given limited household assets, though through exploitative labour arrangements. Workers reported extended working days without access to water or other resources, with unpaid wages persisting weeks (Djerbi, 2024). These conditions suggest that whilst female agricultural labour may generate household-level economic gains through cost reduction, women workers themselves face intensified workloads and constrained capacity to convert labour into wellbeing improvements.

2.5.2 Land Tenure Security and Wellbeing

Ethnographic research characterizes the effect that land tenure security has on wellbeing: landless Sidi Bouzid farm workers experience conditions synonymous with feminized rural poverty (Djerbi, 2024). Women's lack of land ownership constrains bargaining power and limits capacity to contest exploitative conditions. Even where women own small plots, they face disadvantages in accessing subsidised fertiliser and market connections, with male relatives accompanying them to improve procurement chances despite women serving as primary farmers.

International research establishes land ownership and tenure security as critical conditioning factors. Ownership of productive assets and control over resources—including land, seeds, and credit—constitute primary factors shaping women's productivity, empowerment, and capacity to improve household nutritional outcomes (Njuki et al., 2022). In rural China, formal land title certificates and protection from expropriation substantially improve rural women's empowerment and household bargaining power (Han et al., 2019). Despite this, land access alone proves insufficient where complementary resources and decision-making authority remain constrained. In rural Bangladesh, land access did not translate into women's individual income or economic wellbeing—despite increasing aggregate household income—due to limited decision-making power, restricted involvement in income-generating activities, and small plot sizes (Sultana et al., 2024).

2.5.3 Agricultural Technology Adoption and Wellbeing

Studies examining agricultural technology adoption in Tunisia document varied effects. Adoption of agricultural innovations—milking machines and mechanised olive harvesting equipment—correlated with production improvements, income increases, and workload reductions (Najjar & Baruah, 2024).

Conversely, research in Northwest Tunisia reveals technology adoption can generate adverse wellbeing outcomes. Mhadhbi and Napoléone (2022) found that mechanization and intensive input adoption—including high-yield seeds and irrigation systems—displaced farm labourers without corresponding growth in industrial or service sectors to provide alternative employment, thereby intensifying poverty and accelerating rural-urban migration. This approach disproportionately advantaged large, mechanized operations whilst proving unsuitable for small family farms, where technology adoption

generated debt burdens and environmental damage rather than economic gains. Furthermore, labour-saving technologies that enhanced profitability for larger farms undermined traditional communal practices, deepening social inequalities. These divergent outcomes indicate that technology impacts hinge on farm scale, with labour-saving innovations displacing workers where alternative employment is unavailable whilst benefiting capital-endowed households capable of appropriately scaled technology adoption.

International research establishes agricultural technology access as a pertinent conditioning factor. Irrigation systems and motorised equipment demonstrate potential to influence food security and economic circumstances (Ongachi & Belinder, 2025; Fischer et al., 2022). Smart irrigation systems optimise water usage whilst reducing manual water hauling—a task disproportionately assigned to women—thereby alleviating time constraints (Anand et al., 2025). These contrasting findings indicate that technology's relationship with household wellbeing remains contested, with outcomes depending on farm scale, local economic context, and institutional arrangements.

2.6 Literature Synthesis, Gaps and Thesis Contribution

Research across Tunisian and international contexts exhibit complex relationships between female agricultural labour intensification and household wellbeing. Tunisian evidence substantiates how feminization operates through contradictory dynamics: whilst it may generate household-level economic benefits through cost reduction or income diversification (Gaillard et al., 2022; Mazhoud et al., 2025), women workers themselves confront intensified workloads under precarious conditions with limited protections (Djerbi, 2024). Land tenure security and agricultural technology emerge as theoretically important conditioning factors internationally, though their effects prove contested. Formal land ownership can improve women's empowerment and bargaining power (Han et al., 2019; Njuki et al., 2022), yet land access alone proves insufficient where complementary resources and decision-making authority remain constrained (Sultana et al., 2024). The use of agricultural technology has similarly ambiguous potential: whilst innovations may reduce physical burdens and improve productivity (Najjar & Baruah, 2024), adoption outcomes depend critically on farm scale, local economic context, and institutional arrangements (Ongachi & Belinder, 2025; Fischer et al., 2022).

Despite substantial research on agricultural feminization, two critical gaps limit understanding of how feminized labour strategies shape household wellbeing in Tunisia's olive sector. First, prevailing wellbeing measurement approaches emphasize singular dimensions, particularly food security, potentially obscuring divergent responses across wellbeing domains. Agricultural intervention research suggests that aggregated wellbeing measures can mask domain-specific trade-offs, with households experiencing positive outcomes in nutrition whilst facing deterioration in economic capacity or subjective wellbeing (Solomon et al., 2024). This study employs a three-dimensional measurement approach encompassing nutritional security (food diversity and adequacy), economic provisioning capacity (ability to afford essential needs beyond food), and subjective wellbeing (perceived quality of life). This disaggregation enables identification of trade-off patterns wherein households might maintain dietary diversity through feminized labour cost-reduction whilst experiencing deterioration in economic capacity for healthcare or education, or wherein material outcomes remain stable, yet subjective wellbeing declines due to intensified workloads and time poverty. Without disaggregating wellbeing domains, single-dimension measures risk misclassifying necessity-driven coping strategies that maintain survival in one domain at the expense of others as successful adaptation. This three-dimensional approach thus reveals whether feminized labour represents strategic adaptation generating broadly positive outcomes or necessity-driven responses that sacrifice wellbeing in some dimensions to preserve it in others—a distinction critical for understanding livelihood sustainability and identifying appropriate policy interventions.

Second, no identified Tunisian studies explicitly examine whether land tenure security or agricultural technology moderate relationships between female agricultural labour intensity and wellbeing outcomes, despite international evidence establishing these assets as critical conditioning factors (Njuki et al., 2022; Han et al., 2019; Sultana et al., 2024). Whilst Djerbi (2024) points to tenure's relevance for women's bargaining power and Najjar & Baruah (2024) document technology's effects on workload and income, neither examines whether these assets moderate the labour-wellbeing relationship at the household level. This represents a notable gap given Tunisia's distinctive structural and political context.

This study addresses these gaps by applying the SLF 21st Century framework to Tunisian olive smallholders. The central research question asks: How does household reliance on feminized agricultural labour relate to multi-dimensional wellbeing outcomes, and does asset endowment—specifically land tenure security and agricultural technology—moderate these relationships? Three hypotheses guide the analysis: (H1) female labour density positively associates with household wellbeing (nutritional security, economic capacity, subjective wellbeing) through cost-reduction strategies enabling adaptation; (H2) land tenure security moderates this relationship, with households possessing both formal ownership and freedom from investment barriers demonstrating stronger positive associations; and (H3) agricultural technology moderates this relationship, with households accessing labour-saving technologies (irrigation, mechanization, transport) demonstrating stronger positive associations. Hierarchical moderated multiple regression tests these relationships across Tunisia's coast-interior heterogeneity and between family versus hired feminization pathways.

3.0 METHODOLOGY

This chapter details the research design, data sources, and analytical procedures examining feminized agricultural labour and household wellbeing in Tunisia's olive sector.

3.1 Research Design and Data Collection

This study employs cross-sectional quantitative research design using household survey data to examine correlational relationships between feminized agricultural labour and multi-dimensional wellbeing outcomes. The analysis tests three hypotheses derived from the SLF 21st Century through Hierarchical Moderated Multiple Regression (HMMR).

Three regions represent differentiation within Tunisia's olive production landscape: Beja (n=31) encompasses interior cultivation zones, while Sousse (n=20) and Monastir (n=10) represent coastal areas with stronger infrastructure connectivity. The analysis utilizes primary data from the SustInAfrica project (EU Horizon 2020 Research and Innovation Programme under Grant Agreement 861924). Baseline surveys were conducted by trained enumerators between June 2022 and February 2023, coinciding with extreme drought, President Saied's dissolution of democratic institutions, and macroeconomic deterioration (Ash, 2023).

Purposive sampling was employed through local agricultural extension agents (Cellules Territoriales de Vulgarisation) who selected approximately ten olive farmers from six communities to ensure diverse representation across farm sizes, technology adoption levels, and labour compositions. The baseline sample comprised 62 households. After listwise deletion for missing data, the analytical sample ranges from n=54 to n=59 depending on the specific model. Regional stratification models utilize Beja n=28 (3 cases excluded from 31 due to missing predictor data) and coastal n=26 (4 cases excluded from 30 due to missing data).

Data collection involved three integrated survey modules. The socioeconomic module captured household composition, labour allocation with 12-month recall distinguishing family and hired workers by gender, asset ownership including land tenure, and perceived quality of life. The agrophysical module documented land holdings, cultivation practices, technology access (irrigation, mechanized tillage, machinery, transport), and production outcomes. The Food Consumption module employed seven-day dietary recall using standardized food groups aligned with World Food Programme methodology (Specific survey questions detailed in Appendix L).

The survey's disaggregated labour data capturing family and hired workers by gender is rare, as most agricultural surveys aggregate labour into undifferentiated person-days, obscuring substitution dynamics between unpaid female family members and low-wage female hired workers. This enables comprehensive measurement of farm-system female labour density and testing whether relationships differ between family feminization (necessity-driven) and hired feminization (strategic cost-minimization).

3.2 Variable Operationalization

Variable operationalization through the SLF 21st Century is reflected in Figure 2. Three wellbeing dimensions operationalize *Pathways to Making a Livelihood* and address methodological limitations from Section 2.6, enabling detection of domain-specific trade-offs and compensation bias. Food Consumption Score (FCS) operationalizes nutritional security through seven-day dietary recall translated into composite score:

$$(1)\quad FCS = \Sigma(f_i \times w_i)$$

where f_i represents consumption frequency and w_i is nutritional weight (meat/fish and dairy weighted highest at 4; cereals at 2; sugar and oil at 0.5). Scores above 35 indicate acceptable food security.

Basic Needs Index (BNI) operationalizes economic security through household self-assessment of ability to comfortably afford nine essential needs: diverse diet, clothing, medical care, clean water, safe housing, education, transportation, energy, and saving 10% of income. The BNI is calculated as:

(2) $BNI = \Sigma N_i$

where $N_i = 1$ if need i is comfortably afforded, 0 otherwise.

Perceived Quality of Life (PQoL) operationalizes subjective wellbeing through household head assessment of wellbeing change over the previous year, coded as Bad (1), Stable (2), or Good (3).

Female Labour Density Ratio (FLDR) operationalizes *Relational Power* and *Livelihoods in Flux*, measuring farm-system reliance on female labour. Total female labour (family and hired) divided by total labour from all sources:

(3) $FLDR = (F_{family} + F_{hired}) / (F_{family} + F_{hired} + M_{family} + M_{hired})$

where F represents female workers and M represents male workers, subscripted by source. A ratio approaching 1 indicates high female labour reliance; approaching 0 indicates male-dominated systems. For hierarchical regression models, raw ratios were standardized (Z-scored) to mean 0 and standard deviation 1.

Land Tenure Security Index (LTSI) operationalizes *Assets* (physical capital) measuring household resilience against investment barriers through composite combining formal ownership rights and perceived institutional constraints. The ownership score component ($C_{ownership}$):

(4) $C_{ownership} = \Sigma (W_i \times X_i)$

where X_i is a binary indicator for the mutually exclusive tenure category, and W_i represents the assigned weight: own land (1.00), family land (0.80), communal land (0.60), state-owned land (0.40), rented land (0.30), sharecropped land (0.15), and borrowed land (0.10). These weights reflect legal security gradients: full ownership (1.0) provides maximum protection against loss of access and enables long-term investment,

while borrowed land (0.1) represents the most precarious tenure with minimal legal protection and highest eviction risk. Intermediate categories reflect varying degrees of formal documentation, customary rights, and dependence on others' goodwill (Han et al., 2019; Omilola et al., 2021; Azumah et al., 2023). The constraint barrier score (C*barrier*) captures institutional friction eroding the value of formal titles:

(5) C*barrier* = 0.80 × D_Yes + 0.40 × D_Possibly + 0 × D_No

where D_Yes = 1 if household reports tenure constraints preventing land improvements, 0 otherwise; and D_Possibly = 1 if household reports potential constraints, 0 otherwise. The final LTSI combines these components:

(6) LTSI = C*ownership* – C*barrier*

Positive scores indicate ownership benefits outweigh constraints; zero or negative scores indicate constraints negate ownership. For regression models, raw scores were standardized (Z-scored).

Agricultural Technology Index (ATI) operationalizes *Assets* (physical capital) through drudgery-reduction capacity via weighted summation of access to four key technologies:

(7) ATI = (0.40 × SI*rr*) + (0.20 × S*Till*) + (0.20 × S*Mach*) + (0.20 × S*Trans*)

Irrigation (S_*Irr*) receives highest weight (0.40) as water access eliminates manual hauling and stabilizes seasonal labour peaks (Weber et al., 2019; Mazhoud et al., 2025). Irrigation, Tillage, and Transport are treated as multi-tier gradients reflecting physical strain reduction: Irrigation is coded as automated/drip systems (1.0), manual/pump-assisted systems (0.40), or no access (0); Tillage (S_*Till*) as motorized tractor use (1.0), animal-powered tillage (0.50), or manual/no tillage (0); Transport (S_*Trans*) as ownership of trucks, motorized vehicles, tricycles, or animal-drawn carts (1.0), reliance on public transport (0.40), or walking (0). Machinery (S_*Mach*) follows binary specification (1.0=present, 0=absent) for specialized agricultural equipment (See Appendix D). For hierarchical regression models, raw scores were standardized (Z-scored).

Control variables account for structural and human capital factors. Household size operationalizes *Livelihood Characteristics* (total members, Z-scored). Highest

educational attainment operationalizes *Relational Power* (level reached by any adult, ordinal scale 1-4). Farm scale operationalizes *Assets* (natural capital, total hectares, Z-scored). Household lifecycle profile operationalizes *Livelihood Characteristics* (categorical: adult-only or multi-generational with members in 18-64 and 65+ brackets). Regional location operationalizes *Transforming Structures and Processes* (categorical dummy variables for Beja [reference], Sousse, Monastir).

3.3 Data Analysis Strategy

Hierarchical Moderated Multiple Regression in SPSS Version 31.0.1.0 tests whether capital assets moderate relationships between female labour density and wellbeing. Models build sequentially across four blocks. Block 1 (Controls): household size, education, farm scale, lifecycle profile, region. Block 2: introduces FLDR variable. Block 3 (Moderators): adds LTSI and ATI. Block 4 (Interactions): two-way interactions (FLDR × LTSI; FLDR × ATI), testing capital assets moderate labour-wellbeing relationships.

Three sensitivity analyses test robustness. Regional stratification splits sample into Beja versus combined coastal zones, running identical Block 4 models separately testing spatial heterogeneity. Labour pathway decomposition separates FLDR into household female labour percentage (unpaid family) and hired female labour percentage (paid external), testing whether necessity-driven family feminization versus strategic hired feminization exhibit divergent moderation patterns. Tenure component decomposition disaggregates LTSI into ownership score and structural barriers, testing which dimension drives effects and interactions.

3.4 Methodological Limitations

The cross-sectional design fundamentally limits causal inference. Observed associations between female labour density and wellbeing could reflect reverse causality or unobserved confounders including entrepreneurial capacity, social capital, and prior asset accumulation. The analysis establishes that relationships exist and tests asset moderation but cannot definitively determine causation.

The small sample (N=62, analytical n=53-59) constrains statistical power for detecting interaction effects, increasing Type II error risk. The limited sample also prevents subgroup analyses by household type or wealth distribution.

Purposive sampling through government agricultural extension agents introduces systematic selection biases. Findings may not generalize to farmers without extension connections, the most marginalized households avoiding authorities, underrepresented regions, or other Mediterranean olive systems. The concentration in Beja (50%) means findings may disproportionately reflect interior zone dynamics.

The sample comprises predominantly male household heads (98.4% of respondents identified the household head as male, with 95.2% of respondents serving as household heads themselves) (See Appendix C). Male household heads likely anchor assessments on publicly visible economic domains while systematically missing wellbeing dimensions experienced by other household members. This androcentric measurement bias creates differential validity: Perceived Quality of Life captures male subjective perceptions; Basic Needs Index assessments may not reflect what female members can comfortably afford; Food Consumption Score may reflect male perceptions rather than actual consumption patterns where women and children buffer insecurity through meal skipping. Null or positive findings between female labour density and wellbeing outcomes cannot prove labour intensification imposes no costs: these costs may be invisible to male respondents through salience bias, normalized within patriarchal structures, or concealed due to social desirability bias.

Exclusive reliance on quantitative survey data limits understanding of mechanisms. Standardized scales cannot capture qualitative experiences: women's narratives of physical exhaustion, household negotiation dynamics over labour allocation, perceived trade-offs between agricultural work and other responsibilities, or subjective meanings attached to increased farm responsibilities. Without direct interviews with female agricultural workers, the study cannot access experiential knowledge about time allocation conflicts, physical impacts from intensified labour, foregone opportunities, or how women assess whether agricultural intensification represents empowerment or exploitation.

The 12-month labour recall period introduces substantial recall bias. The seven-day dietary recall creates temporal mismatch with annual production cycles: current food consumption may not reflect labour strategies deployed during planting or harvest months, obscuring causal connections particularly for households experiencing seasonal food insecurity.

Moderator variables employ theoretically informed but empirically unvalidated weighting schemes. The Land Tenure Security Index subtraction structure assumes ownership benefits and constraints have equal but opposite magnitudes, yet effects may be asymmetric. The index treats tenure categories as mutually exclusive based on the primary plot, potentially overlooking households operating under multiple simultaneous tenure arrangements. The LTSI is sensitive to the 0.80 constraint penalty; alternative weighting could sharply alter moderation results.

The Agricultural Technology Index assigns irrigation highest weight based on female labour burden literature, yet these values represent discrete ordinal jumps assuming linear progression that may not reflect actual labour saved between technologies. Both indices derive from analytical judgment rather than Principal Component Analysis or respondent-validated rankings, introducing construct validity concerns.

The Female Labour Density Ratio count-based measure does not capture task intensity differences, hours worked, or work conditions, potentially introducing downward bias as women may work longer hours in more physically demanding tasks (Weber et al., 2020). The standardization of variables facilitates cross-moderator comparison but limits interpretability in absolute real-world units. Multiplicative interaction terms impose constant-effect assumptions, potentially oversimplifying non-linear threshold dynamics. The control specification omits potentially confounding pathways including social capital, credit access, gender composition, and off-farm income diversification, creating internal validity threats.

3.5 Ethical Considerations

This study utilizes data collected by the SustInAfrica consortium, which obtained institutional ethics approval. The consortium followed standard ethical protocols including informed consent, data confidentiality, and right to withdrawal. As the author did not participate in primary data collection, this thesis did not involve direct contact with participants. Ethical obligations extend to responsible data interpretation, acknowledging limitations transparently, and framing conclusions cautiously given methodological constraints. The author approaches this research as Western graduate student analyzing consortium-collected data rather than conducting independent fieldwork, recognizing limited contextual knowledge about local farming practices,

gender relations, and community dynamics that field-based researchers and local scholars possess.

4.0 RESULTS

The analysis tests three hypotheses: (H1) female labour density positively associates with wellbeing; (H2) land tenure security moderates this relationship; and (H3) agricultural technology moderates this relationship. Results are organized by outcome dimension.

4.1 Sample Characteristics and Descriptive Patterns

The analytical sample comprises 62 olive-cultivating households across Beja (n=31, 50%), Sousse (n=20, 32%), and Monastir (n=10, 16%) (See Table I). Educational attainment is high (67.7% superior/university), with mean household size of 5.11 members (SD=1.37) and predominantly adult-only composition (69.4%). Farm scale varies substantially (mean=29.13 hectares, SD=50.90, range 0.81-300).

Female Labour Density Ratio ranges from 0 to 0.88 (mean=0.18, SD=0.26, median=0), indicating male-majority labour systems. Among households employing hired labour, female workers earned mean 24.24 TND/day (median=20) versus male workers' 36.22 TND/day (median=35), a 33% wage differential.

Land Tenure Security Index ranges from -0.50 to 1.00 (mean=0.88, SD=0.31), with over half achieving maximum scores. Agricultural Technology Index shows mean 0.66 (SD=0.20), with near-universal transport (89%) and mechanized tillage (95%) but limited irrigation (27%).

All households achieved acceptable food security (FCS mean=125.95, SD=21.09). Basic Needs Index indicates high economic capacity (mean=7.92/9). Perceived Quality of Life has a mean of 2.15 and SD of 0.40 indicating generally stable subjective wellbeing.

Bivariate correlations among key variables are weak to moderate (Appendix E). Female labour density (FLDR) shows minimal associations with asset endowments and wellbeing. Specifically, FLDR correlates weakly with farm size (r=-.095), household size (r=-.063), and the food consumption score (r=.200). The interaction terms show weak correlations: FLDRxTENURE (r=.034 with FLDR) and FLDRxTECH (r=-.094 with FLDR). Among asset and demographic variables, notable correlations include household age composition with Region: Monastir (r=.395) and with household size (r=.250). The

agricultural technology index shows weak negative correlation with FLDR (r=-.220) but positive correlation with education (r=.224) and land tenure security (r=.274). Low to moderate predictor intercorrelations (most |r|<.40) indicate acceptable multicollinearity for regression models.

TABLE I

SAMPLE CHARACTERISTICS AND DESCRIPTIVE STATISTICS

Variable	n	Mean (SD) or %	Median	Range
Sample Distribution				
Beja (interior)	31	50.0%	—	—
Sousse (coastal)	20	32.3%	—	—
Monastir (peri-coastal)	10	16.1%	—	—
Core Demographics				
Household size	62	5.11 (1.37)	5.00	2-10
Farm scale (hectares)	57	29.13 (50.90)	10.00	0.81-300
Superior/University education	42	67.7%	—	—
Labour & Wages				
Female Labour Density Ratio	59	0.18 (0.26)	0.00	0-0.88
Female wage (TND/day)	25	24.24 (16.06)	20.00	15-100
Male wage (TND/day)	18	36.22 (13.97)	35.00	22-80
Assets				
Land Tenure Security Index	62	0.88 (0.31)	1.00	-0.50-1.00
Agricultural Technology Index	62	0.66 (0.20)	0.60	0.13-1.00
Wellbeing Outcomes				
Food Consumption Score	62	125.95 (21.09)	127.75	86.5-182.0
Basic Needs Index (0-9)	62	7.92 (1.38)	8.00	1-9
Perceived Quality of Life (1-3)	62	2.15 (0.40)	2.00	1-3

Note: See Appendix C for complete sample characteristics including detailed labour composition, household demographics, and technology components.

4.2 Main Regression Results

Table II summarizes hierarchical regression models across four blocks: (1) demographic controls, (2) female labour density, (3) moderator variables (land tenure, technology), and (4) interaction terms. Appendix F provides complete HMMR results.

4.2.1 Food Consumption Score

For nutritional security (n=54, R^2=.235), FLDR showed positive but non-significant association (β=0.24, p=.124). Neither land tenure (β=-0.05, p=.768) nor technology (β=0.10, p=.551) displays main effects. Interaction terms were non-significant (Tenure: β=0.12, p=.447; Technology: β=0.18, p=.304). All diagnostics were acceptable (VIF<2.0, Durbin-Watson=1.688) (See Appendix G).

4.2.2 Basic Needs Index

For economic capacity (n=54, R^2=.406), land tenure exhibited significant main effect (β=0.46, p=.002). Female labour density was non-significant (β=0.12, p=.400). FLDR×Tenure approached significance (β=0.31, p=.056). One case showed Cook's D=2.021 (See Appendix H).

Sensitivity analysis (Appendix I) excluding the outlier (n=53) revealed substantive changes: FLDR×Tenure lost significance and reversed (β=-0.24, p=.138), female labour became significant (β=0.34, p=.020), and tenure diminished (β=0.17, p=.254).

4.2.3 Perceived Quality of Life

For subjective wellbeing (n=54, R^2=.249), female labour density exhibited a strong positive association (β=0.31, p=.048). Technology showed strong main effect (β=0.40, p=.016). Tenure showed no relationship (β=-0.13, p=.410). Neither interaction achieved significance (Tenure: β=0.04, p=.799; Technology: β=0.31, p=.074). All diagnostics acceptable (Cook's D max=0.268, VIF<1.62) (See Appendix J).

TABLE II

HMMR COEFFICIENTS AND P-VALUES ACROSS HOUSEHOLD WELLBEING OUTCOMES

Indicator	Block	FLDR	LTSI	ATI	FLDR × Tenure	FLDR × Tech
FCS	2	4.544 (.148)	—	—	—	—
	3	4.877 (.144)	−1.374 (.669)	1.131 (.739)	—	—
	4	5.244 (.124)	−0.952 (.768)	2.115 (.551)	2.811 (.447)	5.333 (.304)
BNI	2	.179 (.413)	—	—	—	—
	3	.215 (.295)	.590 (.005)**	.204 (.333)	—	—
	4	.173 (.400)	.653 (.002)**	.181 (.402)	.438 (.056)	−.041 (.897)
BNI (Without Outlier)	2	.274 (.098)	—	—	—	—
	3	.315 (.053)	.317 (.055)	.235 (.153)	—	—
	4	.404 (.020)*	.205 (.254)	.320 (.069)	−.353 (.138)	.319 (.219)
PQoL	2	.069 (.238)	—	—	—	—
	3	.102 (.089)	−.050 (.387)	.122 (.049)*	—	—

4	.120 (.048)*	−.047 (.410)	.155 (.016)*	.017 (.799)	.165 (.074)

Note: *p < .05, **p < .01. Coefficients shown with p-values in parentheses. FCS = Food Consumption Score. BNI = Basic Needs Index. PQoL = Perceived Quality of Life. FLDR = Female Labour Density Ratio. Block 4 = Full model with controls, labour density, technology, tenure security, and interactions. All coefficients are standardized betas. n=54 for all models except BNI with n=53 (excluded outlier). Controls (household size, education, lifecycle composition, region) included in all tables but not shown.

4.3 Tenure Component Decomposition

Disaggregating the composite LTSI into ownership score and constraint barrier score revealed fundamental asymmetry (Table III). Neither component showed significant effects on FCS (all p>.20 for main and interaction effects).

For BNI, ownership showed weak effects (main: β=0.12, p=.444; interaction: β= -0.03, p=.858). Constraint pathway revealed strong negative main effect (β=-0.50, p<.001) and significant negative interaction (β=-0.30, p=.023). Both components showed null effects on PQoL (all p>.30).

TABLE III

TENURE COMPONENT DECOMPOSITION SENSITIVITY ANALYSIS

Outcome/Predictor	**Ownership Pathway (De Jure)**			**Constraint Pathway (De Facto)**		
	R^2	Adj.R^2	β (p)	R^2	Adj.R^2	β (p)
FCS						
Block 4 (Full model)	.185	.018		.229	.071	
FLDR			.21 (.160)			.21 (.153)
LTSI			.05 (.737)			.09 (.527)
FLDR × Tenure Component			.03 (.839)			-.22 (.145)
BNI (Outlier Excluded)						
Block 4 (Full model)	.167	-.004		.435	.319	
FLDR			.13 (.396)			.08 (.540)
LTSI			.12 (.444)			-.50 (<.001)***
FLDR × Tenure Component			-.03 (.858)			-.30 (.023)*
PQoL						
Block 4 (Full model)	.100	-.084		.118	-.062	
FLDR			.18 (.261)			.18 (.245)
Tenure Component			.05 (.740)			.09 (.551)
FLDR × Tenure Component			.08 (.604)			-.15 (.341)

Note: *p < .05, **p < .01. Coefficients shown with p-values in parentheses. n=54 for all models except BNI with n=53 (excluded outlier). ATI was not entered as a predictor in these decomposition models; the sensitivity analysis isolates tenure effects by replacing the composite LTSI with either its ownership or constraint sub-component alone

4.4 Labour Pathway Decomposition

Decomposing by labour source revealed systematic divergence (Table IV). For FCS, household pathway showed null effects (β=-.06, p=.666) and no interactions. Hired pathway showed positive main effect approaching significance (β=.29, p=.053), with no significant interactions.

For BNI (n=53), household pathway showed null effects (β=-.04, p=.774) with no interactions. Hired pathway showed approaching-significant main effect (β=.27, p=.058) and significant tenure interaction (β=.31, p=.045).

For PQoL, household pathway showed null effects (β=-.06, p=.676) with no tenure interaction, though technology interaction approached significance (β=.30, p=.076). Hired pathway showed approaching-significant main effect (β=.25, p=.092) with approaching-significant technology interaction (β=.31, p=.068).

ATI showed significant positive main effects in both pathways for PQoL (household: β=.40, p=.013; hired: β=.33, p=.025) and in hired pathway for BNI (β=.35, p=.015).

TABLE IV

LABOUR PATHWAY DECOMPOSITION SENSITIVITY ANALYSIS

Outcome / Predictor	**Household Female Labour Pathway**			**Hired Female Labour Pathway**		
	R^2	Adj.R^2	β (p)	R^2	Adj.R^2	β (p)
FCS						
Block 4 (Full model)	.227	.027		.291	.101	
FLDR			-.06 (.666)			.29 (.053)†
LTSI			-.04 (.809)			-.11 (.506)
ATI			.11 (.536)			.15 (.380)
Labour × Tenure			.12 (.457)			.18 (.237)
Labour × Technology			.16 (.360)			.12 (.475)
BNI (Outlier Excluded)						
Block 4 (Full model)	.356	.185		.496	.358	
FLDR			-.04 (.774)			.27 (.058)†
LTSI			.18 (.246)			.10 (.527)
ATI			.27 (.073)†			.35 (.015)*
Labour × Tenure			-.01 (.917)			.31 (.045)*

Labour × Technology			.05 (.732)			.08 (.608)
PQoL						
Block 4 (Full model)	.232	.035		.334	.165	
FLDR			-.06 (.676)			.25 (.092)†
LTSI			-.13 (.414)			-.20 (.207)
ATI			.40 (.013)*			.33 (.025)*
Labour × Tenure			.05 (.766)			.10 (.525)
Labour × Technology			.30 (.076)†			.31 (.068)†

Note. * p<.05. Block 4 = Full model with controls, labour density, moderators, and interactions. Beja = interior sub-humid zone (n=28); Coastal = Sousse + Monastir combined (n=26, semi-arid coastal/peri-coastal).

4.5 Regional Stratification

Regional stratification into Beja (n=28) and coastal zones (n=26) revealed spatial heterogeneity (Table V). For coastal zones, tenure interactions with female labour emerged as significant for food consumption (β=0.515, p=.035) and economic capacity (β=0.328, p=.031), with substantially improved model fit (FCS R^2=.515; BNI R^2=.814). For interior Beja, no significant tenure interactions emerged (all p>.30). Female labour showed approaching-significant effect on economic capacity (β=0.403, p=.151). Neither region exhibited significant female labour main effects across dimensions (all p>.15).

TABLE V

REGIONAL STRATIFICATION: BLOCK 4 MODELS BY GEOGRAPHIC ZONE

Outcome / Predictor	**Beja Interior (n=28)**			**Coastal Zones (n=26)**		
	R^2	Adj. R^2	β (p)	R^2	Adj. R^2	β (p)
FCS						
Block 4 (Full model)	.298	-.053		.515	.242	
FLDR			.149 (.606)			-.055 (.799)
FLDR × Tenure			.286 (.323)			.515 (.035*)
FLDR × Technology			-.257 (.407)			.381 (.127)
BNI (without outlier)						
Block 4 (Full model)	.370	.055		.814	.710	
FLDR			.403 (.151)			-.031 (.818)
FLDR × Tenure			-.210 (.441)			.328 (.031*)
FLDR × Technology			.215 (.463)			.235 (.128)
PQoL						
Block 4 (Full model)	.111	-.334		.415	.086	

FLDR	.031 (.925)	.050 (.835)
FLDR × Tenure	.187 (.563)	.270 (.288)
FLDR × Technology	-.164 (.636)	.446 (.106)

Note. * p<.05.

5.0 DISCUSSION

Results provide partial support for hypotheses. H1 received mixed support: female labour density significantly predicted subjective wellbeing (β=0.31, p=.048) but showed null associations with nutritional security and fragile associations with economic capacity (significant only after outlier removal). H2 received partial support with critical qualifications: investment barriers (but not formal ownership) significantly predicted economic capacity (β=-0.50, p<.001), with moderation effects contingent on regional context (coastal vs interior) and labour source (hired vs household). H3 received no support: technology showed significant positive main effects (β=0.40, p=.016) but did not moderate feminization-wellbeing relationships (all interactions p>.068). These patterns reveal that feminization-wellbeing associations depend on contextual factors not fully specified in these models.

5.1 Feminized Labour as Livelihoods in Flux

The HMMR reveals the significant association with female labour density and subjective wellbeing (β=0.31, p=.048) but null effects on nutritional security (β=0.24, p=.124) and economic capacity (β=0.12, p=.400). This selective pattern—wherein the relative number of female labourers predicts household heads' assessments but not objective provisioning—suggests divergence between subjective and material outcomes. Through the theoretical lens of the SLF 21st Century, this may reflect labour *Assets* reconfiguration under resource scarcity, though male respondents may anchor assessments on farm operations rather than household provisioning.

Sensitivity analysis reveals the economic capacity finding's fragility. The main model (n=54) identified one influential case (Cook's D=2.021). Excluding this outlier (n=53) produced substantive changes: the feminization measure became significant (β=0.34, p=.020), whilst the tenure main effect diminished (β=0.17, p=.254) and the interaction reversed sign and lost significance (β=-0.24, p=.138). This outlier dependence indicates economic capacity associations are not robust, contrasting with the stable subjective wellbeing finding. The divergent patterns across wellbeing dimensions suggest

that female labour density relates to households through distinct mechanisms that remain inadequately specified in these models.

H1 receives mixed support. FLDR significantly predicts one wellbeing dimension (subjective), shows no association with another (nutritional), and indicates fragile associations with the third (economic). Whether this represents adaptation, measurement artifacts from male-dominated samples, or assessment-outcome divergence cannot be determined from the study's observational nature. The data establish FLDR relates to household heads' perceived quality of life but provide limited evidence regarding material improvements.

5.2 The Institutional Mediation of Asset Efficacy and Investment

The HMMR reveals tenure asymmetry: formal ownership shows no effects (all $p>.60$) whilst investment barriers significantly predict economic capacity (main $\beta=-0.50$, $p<.001$; interaction $\beta=-0.30$, $p=.023$). This indicates *Asset* possession does not automatically enable conversion to outcomes through *Transforming Structures and Processes*, whilst barriers constrain capacity. The regression establishes this divergence but cannot identify which factors—credit access, risk aversion, market conditions, soil quality, or other constraints—drive the barrier effect.

Barriers to investment due to tenure constraints strongly predict reduced economic capacity ($\beta=-0.50$, $p<.001$), with the interaction ($\beta=-0.30$, $p=.023$) suggesting constraints for higher-FLDR households. Although, without longitudinal data this cannot determine whether barriers cause reduced capacity, result from it, or both arise from common factors. The mechanisms—whether credit access, technical knowledge, market participation, or other pathways—remain unspecified.

H2 receives partial support with qualifications. Tenure matters, but only investment barriers show effects—formal ownership shows null associations. Effects manifest selectively through economic capacity ($\beta=-0.50$, $p<.001$) but not nutritional security or subjective wellbeing, suggesting constraints influence productive capacity rather than immediate consumption. This dimension-specific pattern implies barriers limit accumulation rather than affecting day-to-day provisioning.

5.3 Regional Heterogeneity

Regional stratification reveals significant tenure moderation in coastal zones (FCS $\beta=0.515$, $p=.035$; BNI $\beta=0.328$, $p=.031$) whilst interior Beja shows null effects (all

p>.30). This spatial heterogeneity indicates tenure-feminization relationships depend on regional context, though caution is warranted given small subsamples (n=28 interior, n=26 coastal). The regression establishes that coastal and interior regions differ in whether tenure moderates feminization-wellbeing associations but cannot identify which specific regional factors drive this divergence.

Multiple factors may explain coast-interior divergence. Infrastructure differences—connectivity to credit, extension, transport networks (Knaepen, 2021)—represent one possibility within *Transforming Structures and Processes*. Still, unmeasured regional differences—market structures, agricultural systems, social networks, ethnic composition, historical factors, environmental conditions—could equally explain patterns. The data establish spatial heterogeneity but cannot adjudicate between explanations.

H2 receives partial support contingent on regional context. Coast-interior divergence suggests tenure moderation depends on broader factors, though mechanisms remain unspecified. Spatial position is relevant for *Asset* conversion, but small subsamples (n=28, n=26) and unmeasured variables limit causal inference.

5.4 Labour Pathway Divergence

Feminization of hired labour (hired pathway) showing significant tenure moderation for economic capacity (β=.31, p=.045) absent in family pathway (β=-.01, p=.917) reveals how *Relational Power* structures differential access to livelihood pathways.

Hiring requires financial *Assets*, indicating deployment by better-resourced households leveraging ownership for investment and expansion. Conversely, family feminization encompasses heterogeneous motivations: strategic cost-minimization versus necessity-driven responses, generating null aggregate effects (all β≤|.06|).

This pathway-specific moderation implicates *Politics of Influence and Access*. Better-capitalized households possessing tenure security and liquid resources can deploy hired feminization strategically perhaps due to greater access to financial resources. Resource-constrained households may rely on family feminization as necessity regardless of tenure status, experiencing different outcomes in accessing hired pathways. Only hired labour showing asset moderation reveals how structural conditions enable some

households to convert feminized labour to gains whilst others experience different outcomes.

Both pathways involve different structural mechanisms. Household economic patterns from hired feminization operate through labour market dynamics and regulatory frameworks. Null family effects may reflect heterogeneous motivations not fully captured in aggregate household-level data.

5.5 Technology as Independent Physical Capital

Agricultural technology shows significant positive main effects on subjective wellbeing (β=0.40, p=.016) and economic capacity in the hired pathway (β=.35, p=.015). Conversely, H3 receives no support: FLDR×Technology interactions remain non-significant across all wellbeing dimensions (all p>.068). This finding indicates technology functions as independent physical capital benefiting households directly rather than conditionally amplifying feminized labour conversion. Technology and feminized labour operate as parallel rather than synergistic pathways to wellbeing.

Null moderation suggests technology benefits households regardless of labour composition, operating independently rather than conditionally. However, the composite index may obscure heterogeneous effects across technology types, and the cross-sectional design cannot determine temporal ordering. Importantly, post-hoc power calculations indicate 80% power to detect medium-sized interactions (f^2=0.15) but insufficient power for small effects (f^2=0.02), meaning the null FLDR×Technology findings cannot definitively rule out small but meaningful moderation patterns given this sample size (n=54-59).

5.6 Synthesis: Structural Positioning and Differential Adaptation Pathways

Applying the SLF 21st Century framework, these findings reveal how labour *Assets* (feminization) relate to wellbeing through *Transforming Structures and Processes* operating at multiple scales. H1 receives mixed support: FLDR predicts subjective but not objective wellbeing, suggesting divergence between household heads' assessments and material outcomes. H2 receives partial support contingent on context: investment barriers (not ownership) constrain capacity; coastal (not interior) regions show moderation; hired (not household) pathways indicate effects. H3 receives no support: technology functions as independent *Physical Capital* rather than moderating feminization. The context-dependence across tenure components, regions, and labour

sources illustrates *Politics of Influence and Access*: *Asset* possession does not automatically convert to outcomes; structural positioning determines whether households can leverage feminization toward wellbeing improvements. Cross-sectional data prevent determining causation, and unmeasured contextual variables limit specification of mechanisms driving these heterogeneous patterns.

6.0 CONCLUSIONS

This chapter synthesizes empirical contributions, interprets findings through the Sustainable Livelihoods Framework for the 21st Century, considers policy implications, acknowledges limitations, and charts directions for advancing understanding of feminized agricultural labour in North African smallholder systems.

6.1 Empirical Findings

The HMMR revealed FLDR's significant association with subjective wellbeing (β=0.31, p=.048) but null effects on nutritional security (β=0.24, p=.124) and economic capacity (β=0.12, p=.400). Sensitivity analysis revealed economic capacity findings depend on one outlier: excluding it (n=53) made FLDR significant (β=0.34, p=.020) whilst tenure effects diminished, indicating fragile associations. Land tenure exhibited asymmetry: formal ownership showed no effects (all p>.60), whilst investment barriers significantly predicted economic capacity (β=-0.50, p<.001; interaction β=-0.30, p=.023). Regional stratification revealed significant tenure moderation for coastal zones (FCS β=0.515, p=.035; BNI β=0.328, p=.031), absent in interior Beja (all p>.30), though small subsamples (n=28, n=26) limit interpretation. Labour pathway decomposition showed household pathway had null effects (all β≤|.06|, p>.65), whilst hired pathway showed significant tenure moderation for economic capacity (β=.31, p=.045). Technology showed positive main effects (subjective β=0.40, p=.016; economic β=0.35, p=.015) but did not moderate feminization-wellbeing relationships (all interactions p>.068).

6.2 Theoretical Interpretation

These findings reveal how structural positioning shapes *Pathways to Making a Livelihood*. *Asset* possession does not automatically convert to wellbeing: formal ownership shows null effects while investment barriers significantly constrain economic capacity (β=-0.50, p<.001), though mechanisms remain unspecified. Regional heterogeneity establishes that *Transforming Structures* operate at multiple scales—

coastal zones show significant tenure moderation while interior regions do not, suggesting infrastructure and market access condition asset efficacy. Labour pathway divergence indicates *Politics of Influence and Access*: only households with financial capital to hire workers show tenure-conditioned benefits, while family feminization shows null effects. Technology operates as independent physical capital rather than amplifying feminization strategies. Cross-sectional data prevent determining whether such results represent adaptation, structural constraint, or measurement artifacts, but they reveal that identical labour strategies produce divergent outcomes depending on structural positioning rather than household agency alone.

6.3 Policy and Practice Implications

If patterns hold in broader contexts and causal relationships can be established, policy implications emerge from the regression findings, particularly requiring validation through direct consultation with female agricultural workers to ensure interventions align with their actual priorities and circumstances.

The finding that investment barriers negatively predict economic capacity (β=-0.50, $p<.001$) suggests that land titling programs addressing formal ownership alone may prove insufficient when households face constraints on productive investment. Interventions might address credit access through microfinance programs offering agricultural-specific products with flexible repayment (Sultana et al., 2024) and cooperative structures enabling shared investment in technologies requiring capital outlays beyond individual household capacity (Liu et al., 2023). Nevertheless, the economic capacity finding's fragility—significant only after excluding one influential case—requires cautious policy development with pilot testing and iterative evaluation.

The regional heterogeneity finding—coastal zones showing significant tenure moderation (FCS β=0.515, p=.035; BNI β=0.328, p=.031) whilst interior regions show null effects—supports the notion that place-based interventions may prove more effective than uniform national policies (Abbassi & Benhamed, 2025). Interior regions might require public investments in transport infrastructure connecting farms to markets, processing facilities reducing post-harvest losses, and telecommunications infrastructure enabling price information access (Bassem, 2025; El Nour et al., 2024; Ongachi & Belinder, 2025). This notwithstanding, small regional subsamples (n=28, n=26) and unmeasured contextual variables mean this interpretation remains speculative. Whether

infrastructure development, market access improvements, or other unmeasured regional differences drive the coastal/interior divergence cannot be determined from these data.

Technology's consistent positive associations (β=0.40, p=.016) but null moderation suggests climate-adaptive innovations could benefit households regardless of labour composition. Careful qualification is warranted, as technology deployment requires critical examination of several assumptions. First, mechanization and intensive input adoption may undermine traditional communal practices valued by farming communities, generate debt burdens for smallholders, or displace labour without creating alternative employment opportunities (Mhadhbi & Napoléone, 2022). Second, technology interventions assume households want to intensify production when women agricultural workers may prioritize different improvements—childcare support, water access, rest periods, or cash income—over mechanization. Subsidized technology programs risk imposing external solutions to problems women may not identify as primary concerns, while potentially disrupting cooperative labour arrangements and reciprocal community support networks that provide non-material benefits not captured in productivity metrics

6.4 Generalizability and Future Research

The findings reveal specific knowledge gaps requiring targeted investigation. The subjective wellbeing association (β=0.31, p=.048) combined with null objective effects raises questions about divergence between household heads' perceptions and material conditions that cross-sectional male-reported data cannot resolve. Longitudinal research tracking the same households across agricultural cycles could establish whether feminization precedes, follows, or coincides with wellbeing changes, whilst direct consultation with female agricultural workers could determine whether their own assessments align with male household heads' reports. The economic capacity finding's dependence on a single influential case indicates need for larger samples enabling robust subgroup analyses and reducing individual-case leverage on overall patterns.

The coastal and interior heterogeneity—significant moderation in coastal zones (β=0.515, p=.035) but null effects in interior regions—exhibits that context matters but cannot specify which contextual factors drive this divergence. Investigation measuring infrastructure access, market proximity, social networks, and institutional density could identify mechanisms explaining regional variation, enabling more targeted interventions.

The household versus hired pathway divergence similarly establishes differential patterns without specifying why hired feminization shows moderation whilst household feminization shows null effects. Research examining financial capital requirements, decision-making authority, and income control could illuminate whether capital constraints, gender power dynamics, or other factors produce these divergent associations. The null technology moderation finding suggests innovations operate independently of feminization, but whether this reflects technology types, adoption timing, or genuine independence requires investigation.

Critically, all policy implications rest on assumptions about women agricultural workers' preferences that male-reported household data cannot validate. Research must directly engage women workers to understand whether they prioritize technology adoption, formalization, workload reduction, income control, or entirely different improvements than external observers assume.

6.5 Toward Nuanced Gender Analysis

This study establishes associations between feminization and household outcomes without characterizing women's experiences, as findings reflect male household heads' assessments. Whether feminization represents opportunity, constraint, or mixed experiences for women workers cannot be determined from male-reported data. Women may prefer current arrangements or value work despite demands; they may prioritize improvements other than technology, formalization, or workload reduction that external observers assume beneficial. The regression findings establish that feminization-wellbeing relationships depend on contextual factors—tenure components, regional location, labour source—though mechanisms remain unspecified. Effective policy development requires direct consultation with female agricultural workers to understand their actual priorities rather than imposing external assumptions about their needs.

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APPENDICES

Appendix A: The DFID Sustainable Livelihoods Framework (SLF)

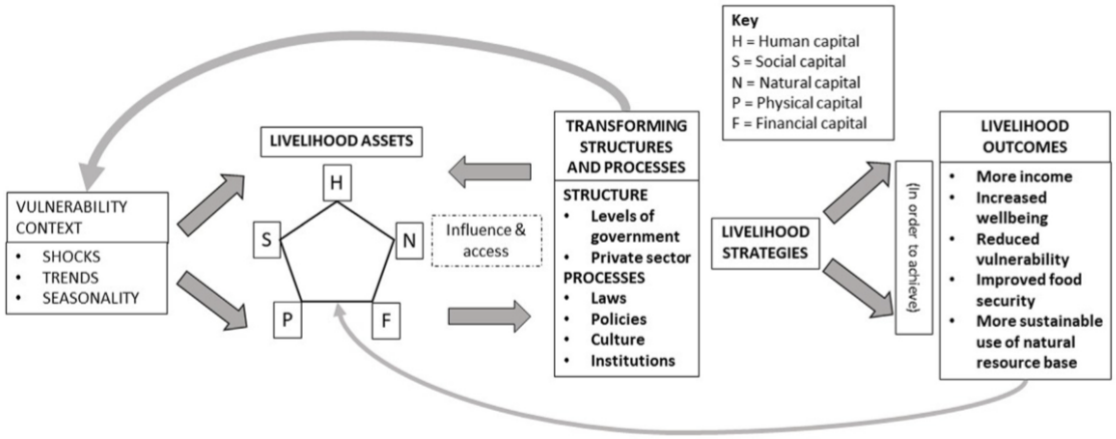

Fig. 2. The DFID Sustainable Livelihoods Framework (SLF) (Source: redrawn from DFID 1999).

Figure 1: The DFID Sustainable Livelihoods Framework (Carney, 1999; Redrawn by Natarajan et al., 2022)

Appendix B: Study Variables and Contextual Factors Projected onto SLF 21st Century

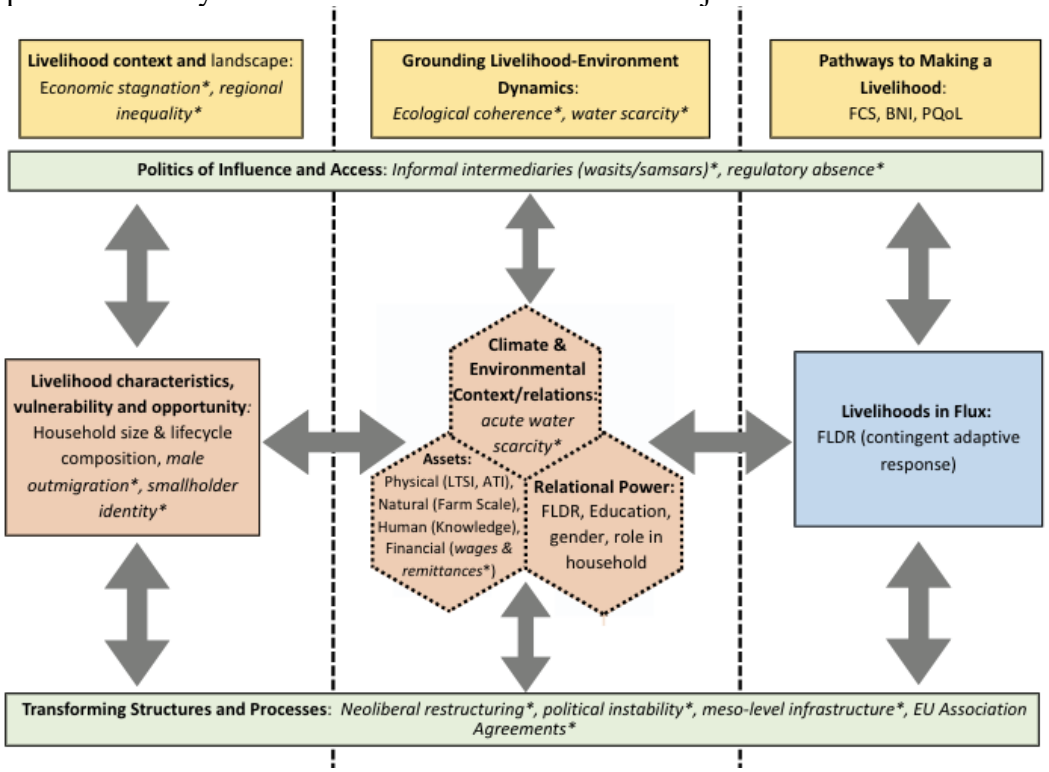

Figure 2: Study Variables and Contextual Factors Projected onto SLF 21st Century (Natarajan et al. (2022), overlayed with own work)

Appendix C: Complete Sample Characteristics and Descriptive Statistics

Variable	n	Mean (SD) or %	Median	Range
HH Structure and Demographics				
HH size (members)	62	5.11 (1.37)	5.00	2-10
Highest education: Superior/University	42	67.7%	—	—
Lifecycle: Adult-only (<64 years)	43	69.4%	—	—
Lifecycle: Multi-generational	19	30.6%	—	—
Farm scale (hectares)	57	29.13 (50.90)	10.00	0.81-300
HH head gender: Male	61	98.4%		
HH head gender: Female	1	1.6%		
HH Respondent role: Head	59	95.2%		
HH Respondent role: Child	3	4.8%		
Respondent Prepares Meals	5	8.1%		
Respondent Does Not Prepare Meals	57	92%		
Labour Composition				
Female Labour Density Ratio (FLDR)	59	0.18 (0.26)	0.00	0-0.88
Adult female family workers	62	0.15 (0.36)	0.00	0-1
Adult male family workers	62	1.35 (0.79)	1.00	0-4
Hired female workers	59	2.49 (6.39)	0.00	0-45
Hired male workers	59	4.37 (3.18)	4.00	1-16
Gender Wage Gap				
Female hired wage (TND/day)	25	24.24 (16.06)	20.00	15-100
Male hired wage (TND/day)	18	36.22 (13.97)	35.00	22-80
Absolute wage gap (TND/day)	—	11.98	—	—
Relative wage gap (%)	—	33.1%	—	—
Asset Endowments				
Land Tenure Security Index (LTSI)	62	0.88 (0.31)	1.00	-0.50-1.00
Agricultural Technology Index (ATI)	62	0.66 (0.20)	0.60	0.13-1.00
Irrigation access (%)	62	26.8%	—	—
Mechanized tillage (%)	62	95.2%	—	—
Heavy machinery (%)	62	100% (mode)	—	—
Transport access (%)	62	89.4%	—	—
Wellbeing Outcomes				
Food Consumption Score (FCS)	62	125.95 (21.09)	127.75	86.5-182.0
Basic Needs Index (BNI, 0-9 scale)	62	7.92 (1.38)	8.00	1-9
Perceived Quality of Life (1-3 scale)	62	2.15 (0.40)	2.00	1-3
Regional Distribution				
Beja (interior, sub-humid)	31	50.0%	—	—
Sousse (coastal, semi-arid)	20	32.3%	—	—
Monastir (peri-coastal)	10	16.1%	—	—

Appendix D: Variable Composition and Survey Question Sources

Variable	Survey Source	Operationalization
Dependent Variables		
Food Consumption Score (FCS)	Mod3-Q11	Σ(Days consumed × Weight) for 8 groups: Cereals (×2), Pulses (×3), Vegetables (×1), Fruits (×1), Meat/fish (×4), Milk/dairy (×4), Sugar (×0.5), Oil (×0.5).
Basic Needs Index (BNI)	Mod1-Q82	Σ of 9 binary items (1=can afford, 0=cannot): Diverse diet, Clothing, Medical care, Clean water, Safe housing, Education, Transport, Energy, 10% savings. Range: 0-9.
Perceived Quality of Life (PQoL)	Mod1-Q23	Overall QoL change vs. previous year: 1=Bad, 2=Stable, 3=Good.
Independent Variables		
Female Labour Density Ratio (FLDR)	Mod1-Q12; Mod2-Q35	(Female family + Female hired) / (Total family + Total hired). Range: 0-1.
Moderator Variables		
Land Tenure Security Index (LTSI)	Mod1-Q46; Mod1-Q49	Ownership Score - Constraint Barrier. Ownership: Own=1.0, Family=0.8, Communal=0.6, State=0.4, Rented=0.3, Sharecrop=0.15, Borrowed=0.1. Constraint: Yes=0.8, Possibly=0.4, No=0. Range: -0.5 to 1.0.
Agricultural Technology Index (ATI)	Mod2-Q45, Q53/Q55, Q60; Mod1-Q22	Weighted sum: 0.40×Irrigation + 0.20×Tillage + 0.20×Machinery + 0.20×Transport. Each binary (0/1). Range: 0-1.
Control Variables		
Region	Mod1-Q1	Categorical: Beja (reference), Sousse, Monastir.
Farm Scale	Mod1-Q43	Total land holdings in hectares (Arable + Fallow + Woodlots + Pasture).
Household Size	Mod1-Q8, Q9	Total household members across all age groups.
Highest Education	Mod1-Q10-Q11	Maximum attainment: 1=None/Incomplete primary, 2=Primary, 3=Secondary, 4=Superior/University.
Lifecycle Composition	Mod1-Q9	Categorical: Adult-only (<64) or Multi-generational (includes ≥65).
Descriptive Variables		
Gender Wage Gap	Mod2-Q37	Female vs. Male hired worker wages (TND/day).
Respondent Gender	Mod3-Q7	Male/Female/Both present.
Respondent Role	Mod1-Q5	Household head, Spouse, Child, or Other.
Meal Preparer	Mod3-Q10	Binary: Respondent is primary meal preparer (Yes/No).

Note: Survey questions sourced from SustinAfrica, EU Horizon 2020 Grant Agreement N° 861924, variable construction own creation. Mod1 = Module 1, Socioeconomic Survey; Mod2 = Module 2, Agrophysical Survey; Mod3 = Module 3, Food Consumption Survey.

Appendix E: Pearson Correlation Coefficients

Variable	1	2	3	4	5	6	7	8	9	10	11	12
1. FCS	1.00											
2. Region: Sousse	-0.23	1.00										
3.Region: Monastir	0.01	-0.26	1.00									
4. Farm Size (Z-Score)	0.24	-0.32	-0.15	1.00								
5. HH Size	-0.22	-0.02	0.09	0.07	1.00							
6. HH Age Composition	-0.06	0.00	0.40	-0.22	0.25	1.00						
7. Edu. level	-0.04	-0.27	0.24	0.14	0.22	0.16	1.00					
8. FLDR	0.20	-0.11	0.35	-0.10	-0.06	0.06	0.07	1.00				
9. ATI	-0.08	0.04	0.03	-0.13	0.06	0.11	0.22	-0.22	1.00			
10. LTSI	-0.17	0.32	0.01	-0.23	0.14	0.10	-0.09	0.01	0.27	1.00		
11. FLDR× LTSI	0.16	-0.05	-0.12	0.08	0.11	-0.26	0.12	0.03	-0.02	-0.15	1.00	
12. FLDR×ATI	0.16	0.21	-0.06	0.14	-0.06	-0.18	-0.31	-0.09	-0.32	-0.04	0.30	1.00

Appendix F: HMMR Regression Coefficients: Block 4

Predictor	Food Consumption Score			Basic Needs Index (outlier excluded n=53)			Perceived Quality of Life		
	β	SE	p	β	SE	p	β	SE	p
Control Variables									
Farm Scale	.202	.128	.209	.393	.141	.009	-.082	.158	.605
HH Size	-.229	.150	.131	-.155	.132	.244	.080	.148	.590
Highest Education Level	-.069	.163	.671	.118	.142	.410	-.202	.162	.211
Lifecycle Composition	.129	.163	.429	.017	.138	.903	.075	.160	.640
Region: Sousse	-.206	.166	.219	.000	.145	.999	.016	.167	.922
Region: Monastir	-.088	.173	.612	-.139	.152	.366	-.213	.173	.218
Main Effects									
FLDR	.244	.157	.124	.336	.142	.020	.314	.156	.048
LTSI	-.046	.154	.768	.174	.152	.254	-.128	.154	.410
ATI	.097	.162	.551	.267	.154	.069	.399	.160	.016

Interaction Effects									
FLDR × Tenure Security	.121	.158	.447	-.236	.157	.138	.040	.157	.799
FLDR × Technology	.179	.172	.304	.196	.157	.219	.311	.171	.074
Model Summary									
Constant	126.86	3.10	<.001	7.69	0.19	<.001	2.13	0.06	<.001
R^2	.235	—	—	.423	—	—	.249	—	—
Adjusted R^2	.034	—	—	.268	—	—	.053	—	—
F-statistic	1.170	—	.336	2.601	—	.016	1.270	—	.280

Note. n=54 for all models except BNI (n=53, outlier excluded) (Block 4 full models). β = standardized regression coefficient; SE = standard error; p = significance value. Reference category for region: Beja (interior, sub-humid). All continuous predictors are standardized (z-scores). † p<.10, * p<.05, ** p<.01, *** p<.001. HH = Household

Appendix G: Food Consumption Score Model Diagnostics

Diagnostic	Minimum	Maximum	Mean	SD
Predicted Value	104.54	146.38	126.86	10.64
Residual	-37.92	49.32	0.00	19.21
Standardized Residual	-1.76	2.29	0.00	0.89
Studentized Deleted Residual	-2.10	2.81	0.01	1.05
Cook's Distance	0.00	0.40	0.03	0.07
Leverage (Centered)	0.06	0.61	0.20	0.13
Durbin-Watson	—	1.69	—	—
Maximum VIF	—	1.62	—	—

Note. n=54. Durbin-Watson statistic = 1.688 (acceptable range 1.5-2.5, indicates no substantial autocorrelation). All standardized residuals within ±3 SD. No Cook's D values exceed 1.0 threshold, indicating no influential outliers. All VIF values <2.0 indicate acceptable multicollinearity.

Appendix H: Basic Needs Index Model Diagnostics (outlier included)

Diagnostic	Min.	Max.	Mean	SD
Predicted Value	4.39	9.84	7.75	1.02
Residual	-3.39	2.49	0.00	1.16
Standardized Residual	-2.58	1.91	0.00	0.89
Studentized Deleted Residual	-5.14	2.49	0.01	1.03
Cook's Distance	0.00	0.29	0.03	0.06
Leverage (Centered)	0.06	0.60	0.19	0.12
Durbin-Watson	—	1.29	—	—
Maximum VIF	—	2.021	—	—

Note. N=54 (outlier included). One VIF value >2, excluded in the following regression for proper inference.

Appendix I: Basic Needs Index Model Diagnostics (outlier excluded sample, n=53)

Diagnostic	Min.	Max.	Mean	SD
Predicted Value	5.18	9.84	7.75	1.02
Residual	-2.84	2.49	0.00	1.16
Standardized Residual	-2.18	1.91	0.00	0.89
Studentized Deleted Residual	-2.83	2.49	0.01	1.03
Cook's Distance	0.00	0.29	0.03	0.06
Leverage (Centered)	0.07	0.60	0.19	0.12
Durbin-Watson	—	1.28	—	—
Maximum VIF	—	1.62	—	—

Note. n=53 (outlier excluded). All VIF values <2.0 indicate acceptable multicollinearity. Model diagnostics for the outlier-excluded sample are acceptable for inference.

Appendix J: Perceived Quality of Life Model Diagnostics

Diagnostic	Minimum	Maximum	Mean	SD
Predicted Value	1.60	3.00	2.13	0.20
Residual	-0.90	0.89	0.00	0.34
Standardized Residual	-2.36	2.34	0.00	0.89
Studentized Deleted Residual	-3.07	2.69	0.01	1.07
Cook's Distance	0.00	0.27	0.03	0.06
Leverage (Centered)	0.06	0.61	0.20	0.13
Durbin-Watson	—	2.061	—	—
Maximum VIF	—	1.62	—	—

Note. n=54. Durbin-Watson statistic = 2.061 (ideal value near 2.0, indicates no autocorrelation). All Cook's D values <1.0, indicating no influential outliers. One studentized deleted residual slightly exceeds ±3 threshold (-3.07) but with low Cook's D (0.06), indicating it does not substantially bias coefficient estimates. Model diagnostics acceptable for inference. All VIF values <2.0 indicate acceptable multicollinearity

Appendix K: Interview Questions Utilized from Household Survey

Module 1: Socioeconomic Survey

Q1. Community – Region *1. Beja. 2. Sousse. 3. Monastir.*

Q5. Role in the household. *1. Head of household 2. Husband 3. Wife 4. Child 5. Grandchild 6. Parents 7. Siblings 8. Other family members (includes household helpers) 9. Responsable/autre mandataire du propriétaire.*

Q8. How many people live in this household?

Q9. We would like to know how many people live in the household by age group and gender. *Female/Male/Total for: Children (0-9 years); Juveniles (10-17 years); Adults (<64 years); Adults (65+ years).*

Q10-11. We would like to know the educational attainment level of the females (Q10) and males (Q11) in the household. *Male and Female Children/Juveniles/Adults/Total for: Never went to school or did not complete primary; Primary education level; Secondary education level; Superior education level.*

Q12. How many people in the household work on farm activities in the household? We would like to know how many people in the household work on farm activities in the household by age group. [Enumerator: Children (0-9 years old), Juveniles (10-17 years old), Adults (18+ years old)]. Record Female/Male/Total [Integer] for: Children (0-9 years); Juveniles (10-17 years); Adults (18+ years); Total.

Q13. Country *1. Tunisia 2. Egypt 3. Niger 4. Burkina Faso 5. Ghana*

Q22. What are the means of transport used by the people in the household? *Own motorbike; Oxen or horse (cart); Own car; Public transport; Other.*

Q23. What is your opinion of the overall quality of life (e.g. in terms of time, money and lifestyle) on the farm compared to the previous year? *1. Good 2. Not good, not bad 3. Bad*

Q43. We would like to ask about the size and area uses of the farm? *Record Unit (Hectare/Acre/Other) and Area for: Total size of farm; Arable land; Fallow land; Woodlots; Pasture.*

Q46. Who owns the land? Please indicate which of the following option or options apply to the farm. *Own land and own use; Own land and rent to others; Sharecropped land; Communal land (traditional ownership); Rented land; Borrowed land (Do not pay for usage); State owned land; Family land; Other.*

Q49. Are there practices or investments you would like to implement on your farm but cannot because of tenure constraints? *1. Yes 2. Possibly 3. No*

Q82. Which of the following can you afford comfortably based on your income, without compromising time for weekly rest? *Yes/No for each: Three meals a day for myself and my family that include fruits and vegetables, and meat if I choose to eat it; Appropriate clothing for myself and my family including shoes, clean clothes for school or work, warm clothes in winter, etc; Medical care, including visits to doctors for myself and my family, and prescriptions or medications; Education and school materials for my children; Energy expenses that allow light and adequate heating; Saving of at least 10% of my income.*

Module 2: Agrophysical Survey

Q10. Which crop types and varieties do you cultivate in a normal year (including permanent crops, rotation crops and intercrops or cover crops/trees e.g. olive, mango) and how much land do you allocate to the respective crops? *Crop options: Mango, Pineapple, Vegetables, Maize, Cowpea, Cotton, Olives, Faba bean, barlet, Chamomile, Date palm, Pearl millet, Winter what, Groundnut, Sesame, Sorghum, Cassava, Yam, Pigeon pea, Sweet potato, Fenugreek, Other. For each crop, record: Number of varieties; Area unit of measure (Hectare/Acre/Other); Area.*

Q35. How many people work on the farm in a normal year? *Total number of workers; Which of them were: Adult males; Which of them were: Adult females.*

Q37. What was the average wage by day for the household and hired workers (payment in money in the local currency or in kind)? *Hired Labour Adult Male, Hired Labour Adult Female.*

Q45. Is the farm irrigated? *1. Yes 2. No*

Q47. What is the irrigation method used? *Drop-by-drop irrigation; Buckets of water deposited near the plant; Hose, manually directed to each plant; Sprinkler or pivot irrigation; Ditch or trench directing the water from a deposit/pump; Other.*

Q53. Do you till the soil? *1. Yes 2. No*

Q55. How do you prepare or till your land? *Do you use: Manually (hoe); Animal draft power (e.g. oxen drawn); Mechanized by tractor; No tillage; Use of Zai pits; Use of demi lunes; Other.*
Q60. Do you use heavy machinery such as tractors, plough, trolley/trailers, thresher, fodder cutting machine, generator/diesel pumps, spraying machines? *1. Yes 2. No*

Module 3: Food Consumption Survey
Q7. Interviewee gender. *1. Male 2. Female 3. Both present*

Q10. Is the interviewee the person who prepares or serves food to the HH? *1. Yes 2. No*

Q11. The following information should be collected from the person preparing and serving the food to the household. For each food group, record: (1) How many days in the last 7 was each food group consumed? (2) What was the principal source of the food group? *(1. Own production 2. Purchase 3. Traded goods/services 4. Borrowed 5. Received as gift)*; (3) What was the most common food of this food group? *Food groups: Maize; Rice; Bread/wheat; Teff; Barley; Potatoes; Tubers; Groundnuts and pulses; Fish; Red meat (beef, sheep, goat); White meat (poultry); Eggs; Vegetable oil, fats; Milk and dairy products; Vegetables (including leaves); Fruits; Sweets and sugar.*

Note: Survey instruments administered as part of the SustInAfrica project (EU Horizon 2020, Grant Agreement N° 861924).