UNDERSTANDING THE FACTORS THAT INFLUENCE CEREAL-LEGUME ADOPTION AMONGST SMALLHOLDER FARMERS IN MALAWI

By

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About me !!!

- **Research Background :** Research Fellow at the Centre for Innovation and Industrial Research (CIIR) under MUST.
- Extensive experience in econometric methods using observational data, running large RCTs, experimental auctions, and developing math programming models.

- **Research interests**: Poverty and rural development, agricultural technology and innovations, agricultural marketing, food security and food safety.

  - **Today's Brown bag session:** Smallholder farmers' production decisions → Maize-Legume intercropping.

Outline

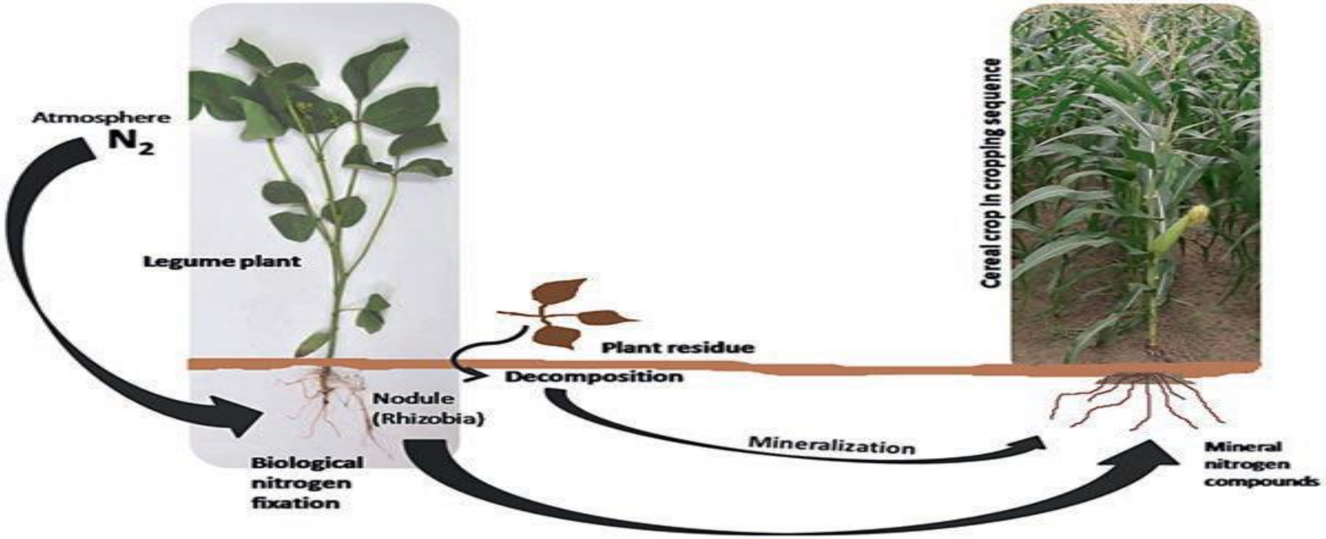
1. Study motivations
2. Literature and contributions
3. Research questions and objectives
4. Methodology
   - Stochastic process
   - Model set up and assumptions
   - Data and sources
5. Results and Discussions
   - Pre-harvest technology adoption
   - Post-harvest technology adoption
6. Conclusions and Policy Implications

Research Motivation

- Sustainable Intensification practices (SI) are cropping systems that conserve the soil structure to maintain and improve soil health and fertility, the environment and natural resources (Silberg et al. 2017).
- These include practices like
  - Agroforestry,
  - Crop rotation,
  - Conservation agriculture
  - and cereal-legume intercropping.

Research Motivation

- SI practices like cereal-legume intercropping are considered to offer several benefits to farmers:
  - Soil fertility and increased productivity (Holden et al. 2018; Silberg et al. 2017)
  - Pest and disease control (Thayamini et al. 2010; Carson, 1989; Carsky et al., 1994)
  - Weed control (Mhango et al. 2013; Rubiales et al., 2006 ; Oswald et al., 2002)
  - Reduce production risk (Layek et al. 2018; Kassie et al. 2015).

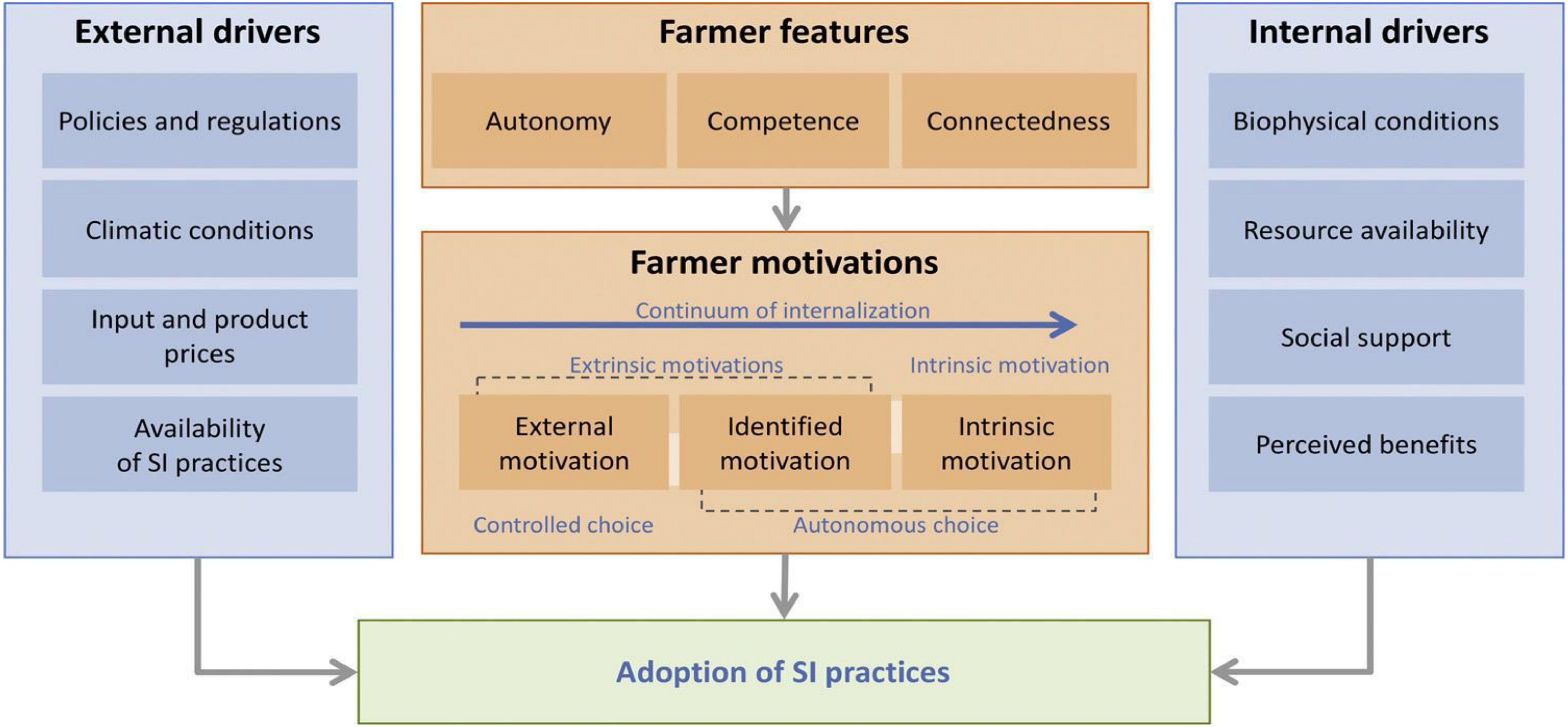


Research Motivation

- However, smallholder farmers' adoption rate of cereal-legume intercropping remains low in SSA.

- In Malawi, wide gap between awareness and adoption of SI practices like cereal –legume intercropping (Ragasa et al. 2019; Jambo et al. 2019; Jaleta, et al. 2015).
  - Why is adoption low?
    - Are the benefits overestimated?
    - Heterogeneity in gains?

Literature on SI Adoption



Literature on cereal-legume adoption

Socio-economic factors-household

- Land constraints
- Labor constraints
- Capital to invest for long-term benefits

SI Adoption

Socio-economic factors-policy

- Limited market access i.e., low yielding seed.
- Limited access to output markets i.e., low output prices.
- Access to SI information i.e., extension services

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Research Questions

1. How do resource constraints (i.e., land ,labor) influence farmers' SI adoption and marketing decisions?

2. How does market access (i.e., input and output market) influence farmers' SI adoption and marketing decisions?

3. How does risk (i.e., uncertainty in yields and prices) influence farm households' SI production and marketing decisions?

Cropping systems or production technologies

- ❑Three crops of interest, that is, maize, beans and pigeon peas
  - ➢ Commonly produced crops and representative of the generic cereal-legume intercropping systems in the country.

- ❑We consider 5 pre-planting technologies or cropping systems:
  - ➢T1: pure stand,
  - ➢T2: maize-beans,
  - ➢T3: maize-pigeon peas,
  - ➢T4: Beans-pigeon peas and ;
  - ➢T5: maize-beans-pigeon peas.


Objective

- We use **dynamic stochastic programming** to evaluate how these constraints influence smallholders' production choices (i.e., cropping systems).

- The model helps to give a snap-shot of how the farmers makes their production and adoption choices under risk (Optimal strategy under risk).

  - **Random variables** included i.e., prices, yields.

  - **Choice variables** include:- cropping system mix, how much to produce, how much to store, how much to sell, how much to purchase.

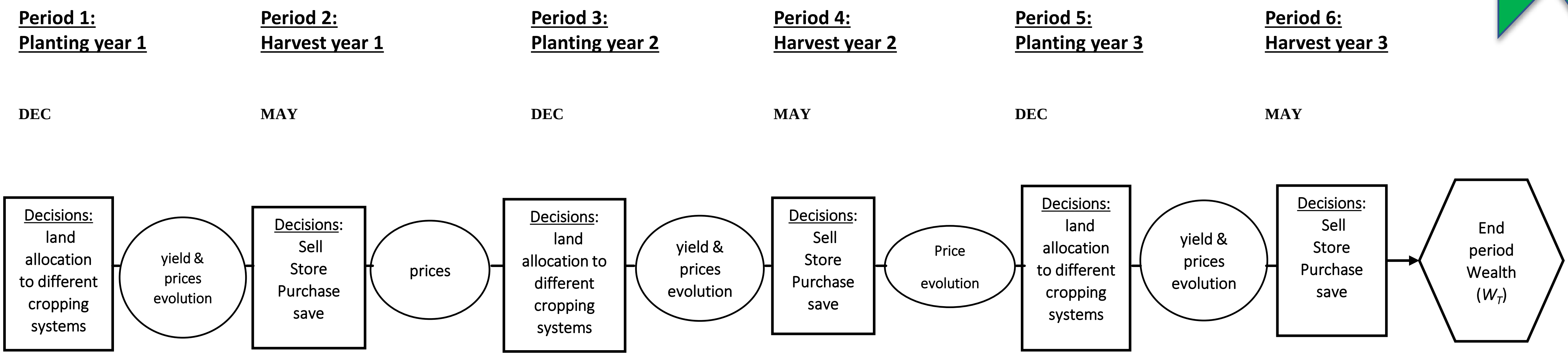
Objective

- We use model scenarios to assess the impacts of alternative policies (i.e. land, labor, input and output market).

- The farm households' optimal farm plans are compared across the scenarios:

Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Status quo	Labor constraint relaxed	Land Constraint relaxed	Access to input markets	Access to output markets	No Constraints

The Stochastic Process



- ❑Finite horizon model spanning 3 cropping years with 2 decision point per year.
  - ➢Seasonal price dynamics on production decisions.
  - ➢Inter-year effects of SI (i.e., medium to long term effects of SI).

- ❑Low productivity in first year with increasing return over time: highest returns are not immediate
  - ➢Poor households limited ability to handle reduction in output for longer-term returns gains.

The Stochastic Process:

- **Decisions at Planting**: Technology or cropping system mix
  - The farmer chooses which cropping system or production technologies to use out of the 5 systems:
  - How much land to allocate to the different cropping systems and
  - We assume that for T2 to T5, the ratio of land allocation to crops within each system is 1:1.
- **Decisions at harvest**: how much to store, sell, or purchase and which storage technology to use.
  - We consider 2 post-harvest technologies: the traditional woven bag and PICS bags and farmer choices which of the two to use for storage.

The Stochastic Process: Prices & Yields

- Yields and prices considered to be jointly distributed and empirically approximated using Gaussian Quadrature(GQ).

- GQ helps to construct a discrete empirical distribution that mirrors their actual historical distribution based on moments (see DeVuyst and Preckel 2007 for details).

- We have three states of nature namely:
    - Good, average and bad for yields;
    - High, medium and low for prices and;
- These states of nature are parameterized using quartiles.

Model and Assumptions

- The household is assumed to be making decisions sequentially from the planting season through to harvests year 3.
- The household then, makes production, storage and marketing decisions to maximize the expected ending wealth.
- A finite-lived household's expected ending wealth expressed as :

$$\textit{Maximize} \qquad E[W] = \sum_{i=1}^{K} W_i P_i \qquad (1)$$

Where:

- W_i *is* household's profits or wealth generated under different states of nature;
- P_i is the probability of the *i*-th state of nature;
- Farmer assumed to be risk neutral.

Model and Assumptions

Resources:

- We assume the farmer has three key production resources: land, labor and cash.
- We have accounting constraints for these at each stage for each state of nature to track the farmer's use of each of the three resources.
- Goal is to ensure the uses of these resources are equal or less that the sources or endowments.
- That is, the objective is optimized subject to these accounting constraints.

Model and Assumptions

- The problem if to max. objective in equation (1) subject to accounting constraints (i.e., uses ≤ sources) below:
- The number of equations for each constraint depend on the realized state of nature in that given stage.

1) Grain accounting constraints for each crop (kgs)
   - i.e., **uses** storage, sales, consumption ≤ **sources**: purchases, inventory, production.
     - ✓ Production -> build in high yielding varieties –access to better input markets.

2) Land constraints (for planting period only in acres).

3) Labor constraints (for each planting & harvest period in hours)
   a) Can use hired labor at harvest

Model and Assumptions

- The constraints (i.e., uses ≤ sources) for each stage include:

4) Inventory capacity constraints (kgs)

5) Cash accounting constraints (in MK)
   - i.e., **uses** savings, household expenses, grain purchases, production costs, labor costs ≤ **sources**: grain sales, remittances or wages, savings carried over.
   - grain sales= build in access to better output markets ->higher prices.

Data and Sources

Parameters	Details	Units	Sources
Prices	1989 to 2016 (Monthly)	(MK/kg)	FAO /AMIS data
Yields	1989 to 2016 (Annual)	(kg/ac)	FAO /AMIS data
Grain Consumption	2016/17 surveys	kgs	IHS4 Household module G1to G3
Expenditures	2016/17 surveys	MK	IHS4 Household module G1to G3
labor	2016/17 surveys	Hours	IHS4 Agricultural Module D
land	2016/17 surveys	acres	IHS4 households Data
PHL	Recent estimate	Loss rate	APHLIS website
Transaction Costs	IHS data	MK	IFPRI Key Fact Sheets
Initial endowments	IHS data	Kgs, MK	IFPRI Key Fact Sheets
Variable costs	IHS data	MK	IFPRI Key Fact Sheets
Inventory Capacity	IHS data	kgs	IFPRI Key Fact Sheets
Minimum wage	2018 MoL	MK/hour	Ministry Labor

Results and Discussions

Notations to Note :

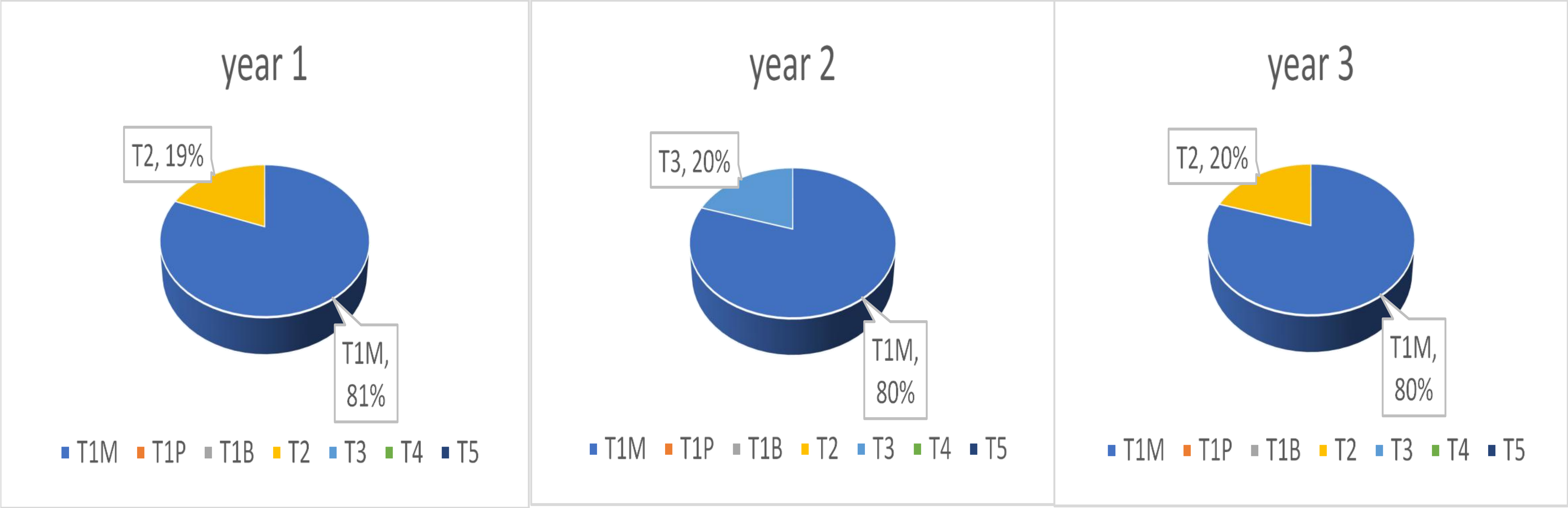
- T1M is pure stand maize;
- T1P is pure stand pigeon peas;
- T1B is pure stand common beans;
- T2 is double intercropping of maize with beans;
- T3 is double intercropping of maize with pigeon peas;
- T4 is legume double intercropping; and
- T5 is triple cropping of maize, beans and pigeon peas.
- Total landholding is 1.5 acres

Results and Discussions

❑Scenario 1: Status Quo

- Subsistence approach with T1 (Pure stand-maize) dominating the share of land throughout the 3-year planning horizon.
- 80 % of the farmland is allocated to T1 with the rest allocated to either T2 or T3.

SCENARIO 1: THE STATUS QUO (BASELINE)

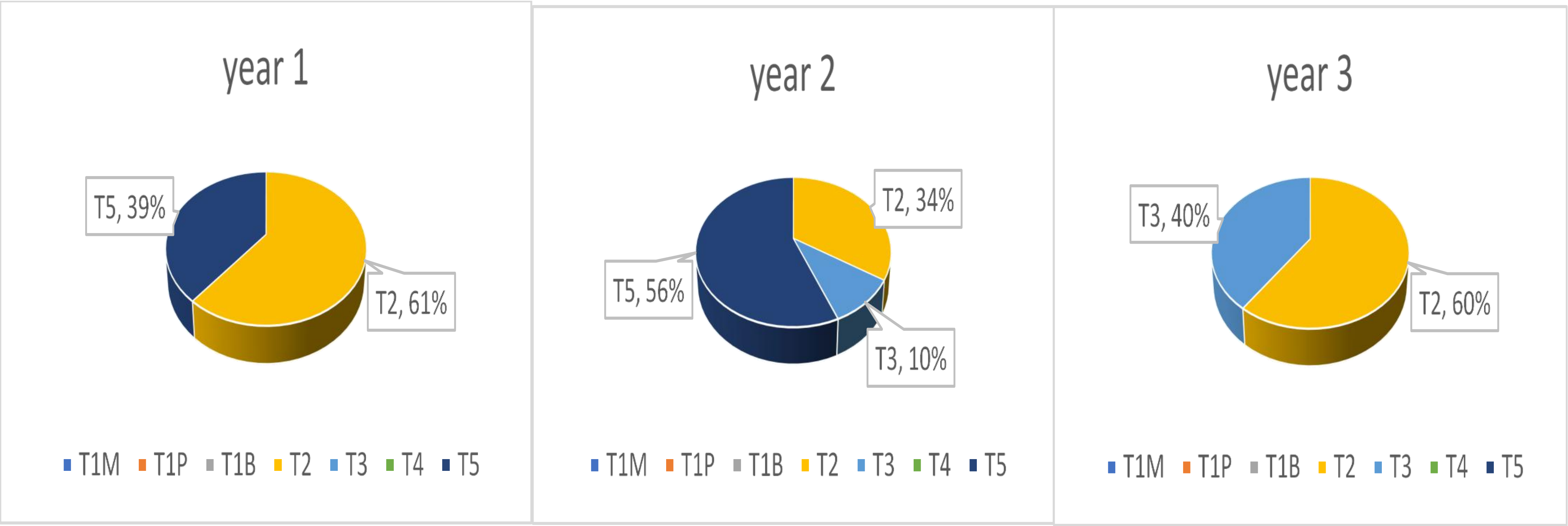


Results and Discussions

❑Scenario 2: labor relaxed

- ➢On average the farmer's optimal plan is to consistently allocate land to intercropping maize with beans and/or pigeon peas: technologies: T2, T3 or T5).
- ➢Labor intensification strategy.

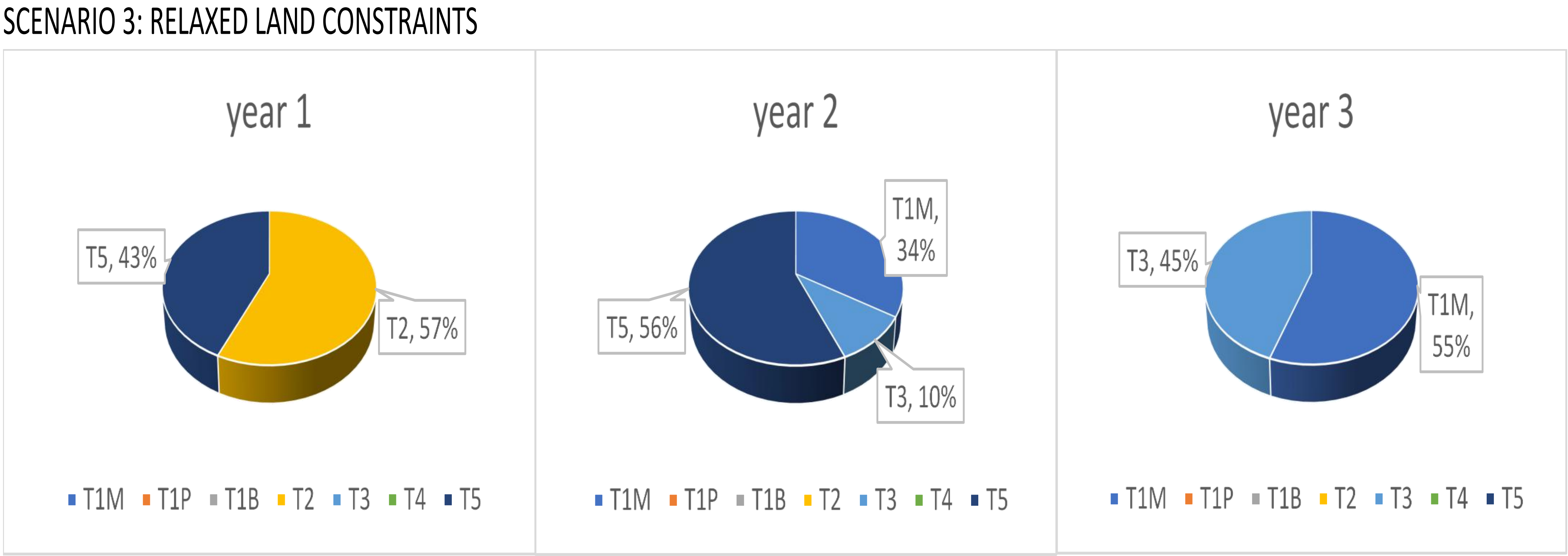
SCENARIO 2: RELAXED LABOR CONSTRAINTS



Results and Discussions

Scenario 3: land relaxed

- Over 40 % of the land allocated to triple cropping of maize and legumes (T5) for the 1st and 2nd cropping cycles in our planning horizon
- More intensive crop diversification with pure stand maize (T1) and T4 not part of the optimal production plan

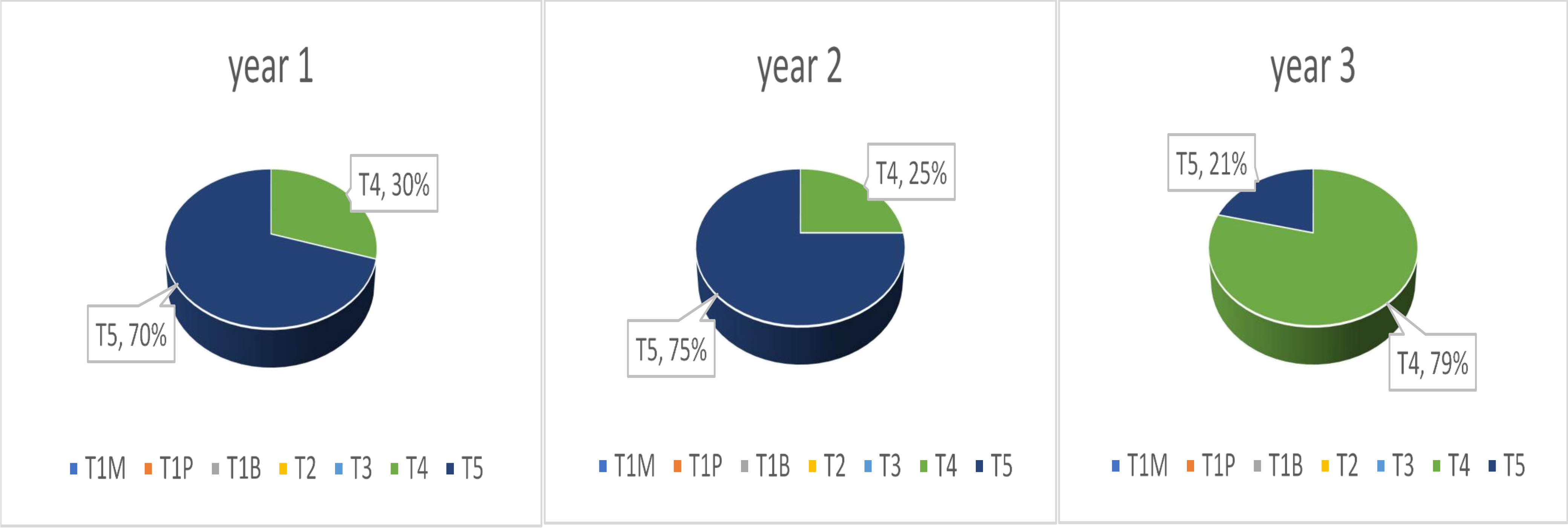


Results and Discussions

Scenario 4 : Yields improved

- Model suggest a production plan that only has T4 and T5 & T4 taking up to about 30 % of the total farmland.
- Legume-orientated cropping systems.

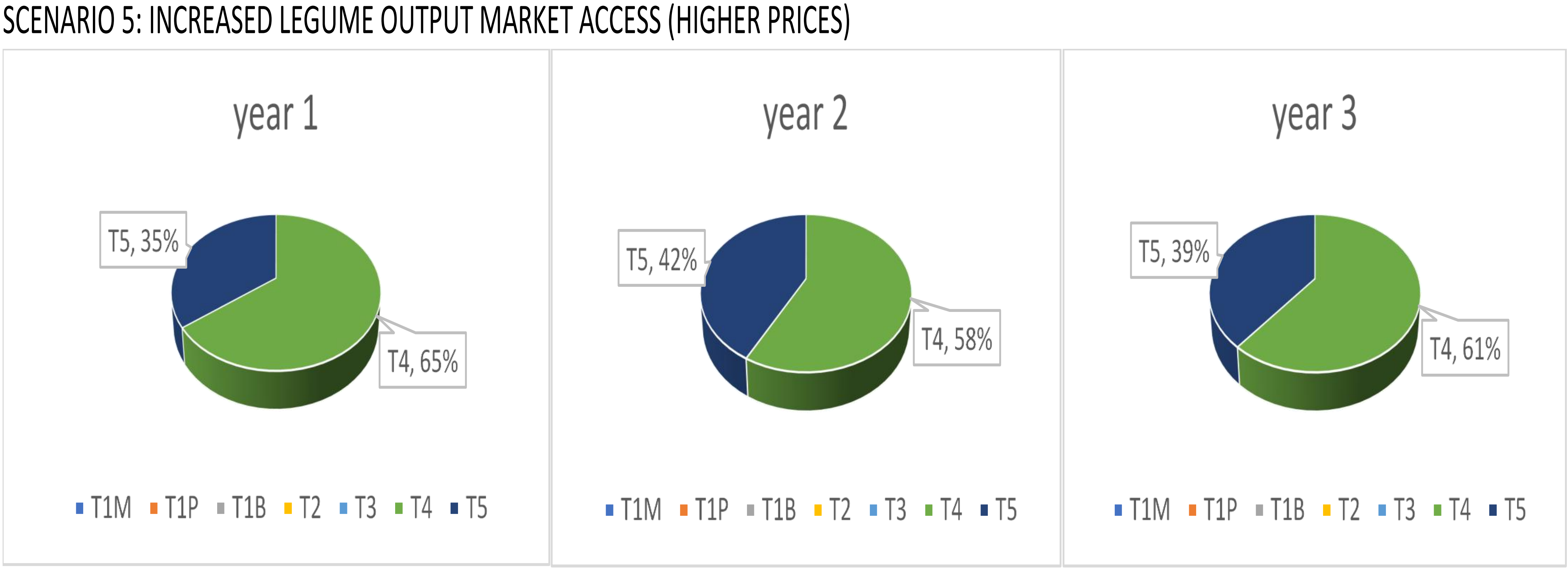
SCENARIO 4: INCREASED LEGUME INPUT MARKET ACCESS (IMPROVED YIELDS)



Results and Discussions

Scenario 5 : Higher output prices

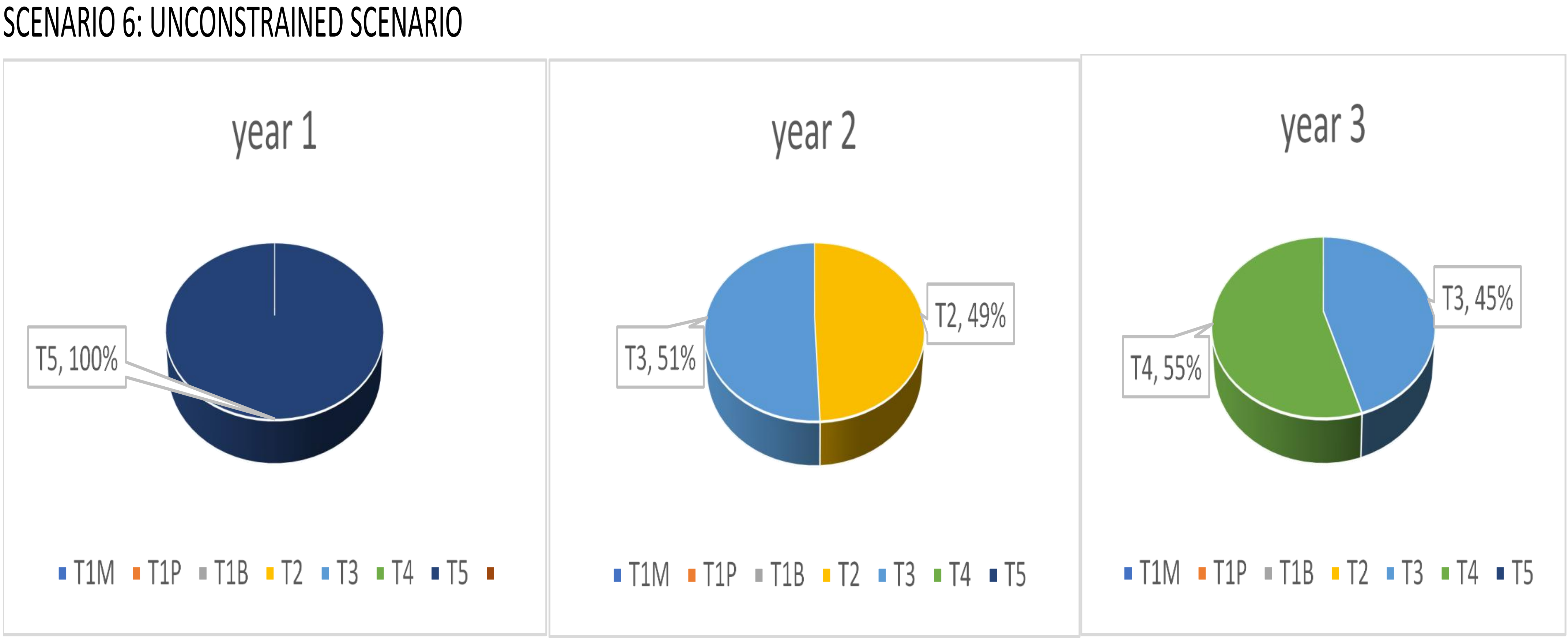
- Similar solution patterns as in scenario 4 where only T4 and T5 are part of the optimal production plan.
- However, in this scenario, close to over 50 percent of the total farmland is allocated to T4.



Results and Discussions

❑Scenario 6: Unconstrained (Targeted)

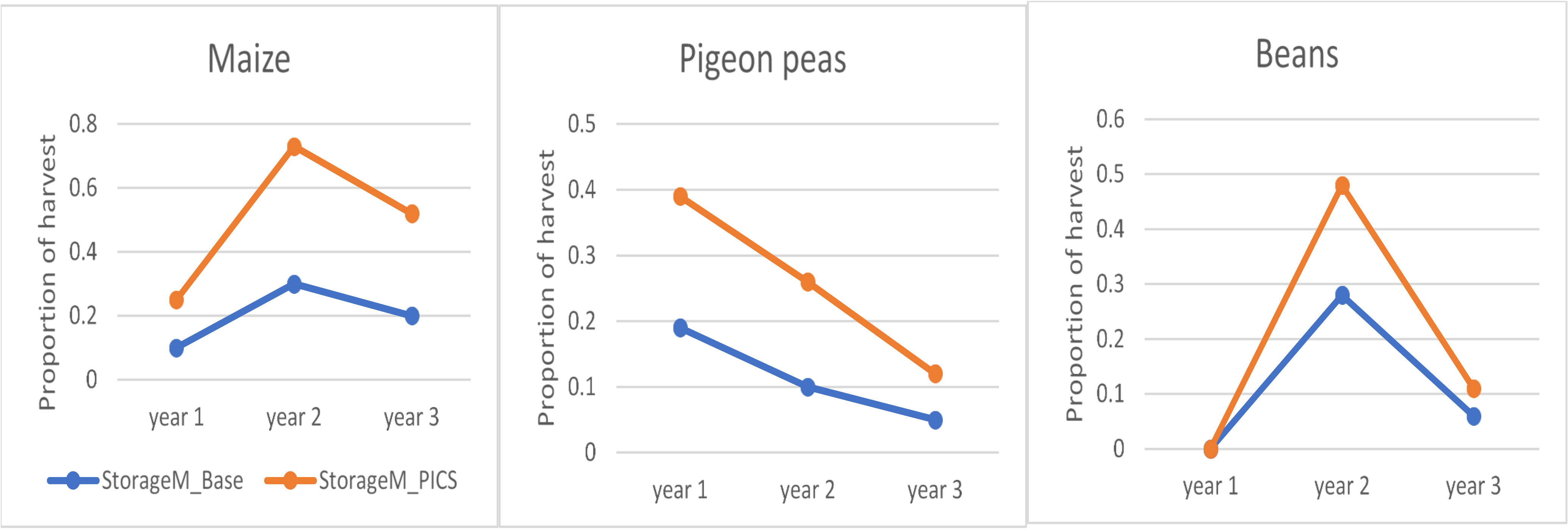
➢ Optimal production plan is to allocate all the land to T5 in year 1 and then downscale to either T2, or T3, or T4 in years 2 and 3.



Post-harvest technology use

- In Scenario 7 has the farmer storing a much higher proportions of his harvest compared to the baseline scenario.
- Example : Maize: 10 to 30 % of maize harvest is stored with ordinary woven bags but this increases to 22 to 73 % with PICS bags.

SCENARIO 7: PERCENT CROP STORAGE AT HARVEST FOR BASELINE WOVEN BAG VS. RELAXED STORAGE CONSTRAINTS



Conclusions

- The model results help to show the impact of the resource (land and labor) and market (input or output markets) constraints on farmers cropping system choice.

1. Relaxing labor constraints by doubling the farm household's labor endowments pushes the farmer towards more labor-intensive production systems involving intercropping of maize with beans and/or pigeon peas.

2. Increasing access to high yielding varieties and high-value markets also show that the farm household will move towards a relatively more legume-based cropping pattern.

3. The lack of effective storage technologies may be influencing farmers rom participating in grain storage in the post-harvest period.

Key Policy Implications

a) Need for policy that could help increasing access to high yielding varieties and high-value markets for smallholder farmers .

b) Need increase farmers access to improved and effective storage technologies.

- Model helps to illustrate how different factors (land, labor, market access, technology access) affect smallholder farmers' decisions in Malawi.

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Parameters for Baseline Model

Parameter	Value	Units	Source
Landholding	1.5	Acres	IHS4 Data: Agriculture Module B1
Household expenditure	18,386	MK per month	IHS4 WB Household Module G1 to G3
Maize consumption	109	Kgs per month	IHS4 Data: Household Module G1 to G3
Pigeon peas consumption	10.5	Kgs per month	IHS4 Data: Household Module G1 to G3
Beans consumption	14	Kgs per month	IHS4 Data: Household Module G1 to G3
Household size	4	Persons	IHS4 WB aggregate consumption per capita
PHL maize	4.1	percent	APHLIS website
PHL Pigeon peas	12	percent per month (Estimate/proxy)	Affognon et al. 2015; Ambler et al. 2018
PHL Beans	12	percent per month (Estimate/proxy)	Ambler et al. 2018
Inventory capacity	1,500	Kg	PICS Baseline Survey for RCT 1 Module F1
Trade capacity	250	kgs per month	PICS Baseline Survey for RCT 1 Module F1
Wage per hour	175	Mk per hour	IHS4 Data: Household Module E waged jobs
Hired labor hours	14	hours per week per person	IHS4 HH Module E Casual labor hours
Available hired labor harvest period	1,975	Hours available harvest season	Imputed IHS4 Data: Agriculture Module D & E
Family agricultural labor	12.5	hours per week per person	Malawi IHS4 Report (Page 112)
Available family labor	860	Hours available per season	Imputed IHS4 report (page 112) & Household size
Enterprise revenue	20,821.4	MK per month	IHS4 Data: Household Module E enterprises
Other cash sources	3275	MK per month	IHS4 Data: Household Module E other sources
Cash remittances (Wages + other transfers)	44,296.4	MK per Month	PICS Baseline Survey for RCT 1 Module D1
Cash savings (Initial cash endowments)	85,500	Malawi Kwacha (2016)	IHS4 Data: Household Module P Incomes
Maize stocks (Initial endowments)	295	Kgs	IHS4 Data: Agricultural Module I Sales and Storage
Pigeon peas stocks (Initial endowments)	42	Kgs	IHS4 Data: Agricultural Module I Sales and Storage
Beans stocks (Initial endowments)	35	Kgs	IHS4 Data: Agricultural Module I Sales and Storage

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