Linear Programming-Based Crop Planning for Farm Profit Improvement in Jagdishpur Block, Bihar

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Abstract - Improving farm income in smallholder agriculture requires crop plans that reflect both local resource constraints and realistic economic opportunities. This paper presents a linear programming model for crop planning in Jagdishpur Block, Bhagalpur district, Bihar. Using block-level data on cultivable area, labor availability, crop yields, production costs, and output prices, the model identifies the land allocation that maximizes annual net return. The optimized solution raises estimated net profit from Rs 40.92 crore under the observed crop pattern to Rs 72.33 crore, mainly through expanded allocation to sugarcane and pulse crops. The results also reveal a marked gap between the mathematical optimum and actual farmer practice. This paper argues that the gap is explained less by farmer irrationality than by missing infrastructure in processing, aggregation, procurement, and market support. The analysis illustrates how optimization can guide local agricultural planning while also showing that profitable crop recommendations must be interpreted together with value-chain capacity and implementation constraints.

Key Words: agricultural economics, crop planning, farm profit, linear programming, rural infrastructure, smallholder agriculture

1. INTRODUCTION

Agriculture remains the principal livelihood base in large parts of Bihar, where smallholder farming continues to rely heavily on cereal-centered production systems. In many blocks, including Jagdishpur in Bhagalpur district, Kharif paddy and Rabi wheat dominate the annual crop calendar. This pattern has important food-security value, but it may also constrain farm income when higher-return alternatives exist. From a planning perspective, the central question is whether the observed crop mix reflects an efficient use of available resources or whether it is shaped by institutional and infrastructural constraints that keep farmers away from more profitable combinations. Linear programming has long been used in agricultural economics to analyze such questions [3], [5]. By structuring crop choice as an optimization problem, LP makes it possible to compare the observed allocation of land and labor with the income-maximizing allocation implied by prevailing technical and price parameters. This approach has been applied in a wide range of agricultural settings, including crop-allocation studies, irrigation planning, and regional diversification analysis [4], [8], [9].

Yet an optimized crop plan is not automatically a realistic recommendation. Smallholder decisions are embedded in pro-cerement systems, processing networks, input supply chains, and risk-management behavior. A crop may appear highly profitable in a deterministic model and still remain unattractive in practice if local value-chain support is weak. The present paper therefore combines a profit-maximizing LP analysis with an interpretation of why the solution may not be observed on the ground.

The analysis focuses on Jagdishpur Block, a major agricultural block in Bhagalpur district with approximately 9,345 ha of cultivable land and a reported agricultural workforce of 44,174 persons. The objective is twofold: first, to estimate the profit-maximizing crop allocation using locally grounded data; second, to interpret the difference between the optimized solution and the current crop structure in terms of infrastructure, market access, and institutional support.

The paper is intended as a planning study rather than a claim of causal identification. Its contribution is to use optimization results to reveal where the largest income gaps appear under observed technical coefficients and then to discuss the institutional conditions that would be required before those gains could plausibly be realized.

2. Study Area and Data

The study uses a structured crop-planning dataset compiled for Jagdishpur Block in the lower Gangetic plain of Bihar. The block has 13,810 ha of geographical area, of which about 9,345 ha are cultivable. Seasonal cultivable area is reported as 3,374 ha in Kharif and 3,807 ha in Rabi, while the agricultural year also includes a limited Zaid window. The labor endowment available for agriculture is estimated at 44,174 persons. These block-level land and workforce values are based on Government of Bihar agricultural records and Census-linked demographic reporting assembled for the study [1], [2].

The modeled crop set includes Kharif crops such as paddy, Katarni paddy, maize, arhar, urad, bajra, and dhaincha; Rabi crops such as wheat, maize, gram, lentil, mustard, peas, barley, linseed, and other pulses; and Zaid crops such as maize and moong. Sugarcane is included as a separate annual crop because it occupies land beyond a single season. For each crop, the dataset provides yield, price, cultivation cost, and labor requirement. These parameters were assembled as part of the crop-planning database used for the Jagdishpur optimization model.

Two features of the dataset are worth noting. First, the analysis is spatially specific at the block level rather than being a district-average exercise. Second, the parameterization is designed to support an operational farm-planning problem rather than a purely descriptive statistical account. This allows the study to ask not only what farmers grow, but what the available coefficients imply they could grow under a profit maximizing rule.

Item	Source used in this paper
Study-area and labor parameters	Government of Bihar block records and Census-linked workforce data
Crop coefficients	Agricultural statistics, MSP-linked prices, and ICAR-based cost estimates
Optimization structure	Published LP formulation and Pyomo implementation logic
Reported baseline outputs	Baseline LP run with effective Zaid land fixed at 0 ha
Numerical cross-check	Computational model baseline results file

Table I- Data and Calibration Provenance Used in This Paper

A. Data Provenance

The quantitative inputs summarized in this paper are drawn from the study's crop-planning dataset and model files. Study area and resource values are based on Government of Bihar agricultural records and Census-linked workforce reporting for Jagdishpur Block [1], [2]. Crop-wise yields are taken from agricultural statistics compiled for the planning exercise, while prices are MSP-linked or market-reference values and cultivation costs follow agricultural reports and ICAR-based cost estimates [7]. The profit and allocation figures reported here correspond to the baseline model run and are consistent with the machine-readable baseline output generated by the computational model. In that reported run, effective Zaid land is fixed at 0 ha so that optimized results can be compared with the observed regional cropping pattern on the same reporting basis.

3. Method

The model was implemented in Pyomo and solved using GLPK [6]. The decision variable for each crop is the area allocated to that crop in the relevant season. The objective function maximizes annual net profit:

$$\max Z = \sum_i (Y_i P_i - C_i) A_i$$

where Y_i is yield, P_i is output price, C_i is cost of cultivation, and A_i is area under crop i .

This is a deterministic linear programming framework. It assumes fixed technical coefficients and constant output prices over the relevant planning period. Such assumptions are standard in baseline farm-planning analysis and are useful for identifying the direction of economic pressure in the system, even though they do not capture all real-world uncertainty.

The crop activities are organized seasonally rather than pooled abstractly. Kharif activities include paddy, Katarni paddy, maize, arhar, urad, bajra, and dhaincha; Rabi activities include wheat, maize, gram, lentil, mustard, peas, barley, linseed, and other pulses; and sugarcane is modeled as a long duration annual activity. This seasonal architecture matters because the empirical question is not simply which crop has the highest return, but which crop combination remains feasible when seasonal land occupation and crop duration are respected.

B. Constraints

The model is subject to the following resource limits:

- **Land constraints:** total cropped area in each season cannot exceed available land.
- **Labor constraints:** total seasonal labor use cannot exceed available man-days.

In addition, the broader model framework incorporates crop-structure controls that prevent implausible specialization. Although the focus of this paper is profit improvement rather than conservation, the optimized baseline still reflects an environment in which crop allocation is shaped by basic agricultural planning conditions rather than unconstrained theoretical expansion.

In numerical terms, the baseline run uses 3,374 ha of Kharif land, 3,807 ha of Rabi land, 4,502 ha as the assured irrigation proxy, and seasonal labor endowments of 2,650,440 and 2,208,700 man-days for Kharif and Rabi, respectively. It also retains crop-structure controls that cap cereals at 70% of seasonal area, require a minimum 15% legume share, and impose biodiversity bounds on Katarni paddy. These controls are important because they keep the result tied to an agricultural planning problem rather than allowing the optimizer to choose an unconstrained commercial monoculture.

The model also rests on standard simplifying assumptions: technical coefficients are fixed, output prices are treated as constant, land is perfectly divisible, and the optimization does not internalize marketing frictions, groundwater dynamics, or inter-household heterogeneity. These assumptions matter because they define the difference between the benchmark solution and a policy-ready recommendation.

In addition, the exact output values reported here come from a baseline run in which effective Zaid land is set to zero. This detail matters because the broader framework can represent additional seasonal possibilities, whereas the paper focuses on the benchmark scenario used for direct comparison with observed local conditions.

C. Interpretive Approach

The empirical contribution of the paper lies not only in calculating the optimized plan, but in comparing it with the observed crop pattern in Jagdishpur. The comparison is used to infer which kinds of enabling conditions are absent from the present farm economy. In other words, the paper treats the gap between observed and optimized allocation as a planning signal rather than as evidence of farmer error.

4. Results

A. Current Crop Pattern

The observed crop structure of Jagdishpur is strongly concentrated in paddy and wheat. On the basis of the compiled block dataset, this pattern produces an estimated annual net return of Rs 40.92 crore. Sugarcane occupies a negligible share, and pulses remain limited relative to their modeled profit potential. This baseline is consistent with a low-diversification production system in which the major cereals continue to anchor the annual calendar.

Indicator	Observed	Optimized
Annual Net Return(Rs Crore)	40.92	72.33
Sugarcane Area(ha)	Negligible	2627.9
Pulse Area(ha)	Limited	1658.2
Dominant cereals	Paddy and wheat	Absent
Primary Binding Factor	-	Land

Table II- Observed and Optimized Outcomes

B. Profit Maximizing Allocation.

The optimized crop pattern differs substantially from the observed structure. Under the LP solution, common paddy and wheat disappear from the final allocation because their net returns are lower than those of competing crops under the assumed coefficients. Instead, the model allocates a large share of land to sugarcane and pulses. Sugarcane expands to 2,627.9 ha, while pulse crops collectively occupy 1,685.2 ha. Total annual net return rises to Rs 72.33 crore, an increase of about 85% over the observed benchmark.

This result implies that Jagdishpur is operating far below the income frontier suggested by the model. It also indicates that land, rather than labor, is the dominant limiting factor in the optimized solution. Labor remains relatively slack, which suggests that the present production structure is not constrained primarily by workforce shortage.

The optimized values in Table II are sourced from the baseline model run and checked against the stored computational baseline output. In that solution, the optimized crop mix consists of 240.0 ha of Katarni paddy, 506.1 ha of Arhar, 1179.1 ha of Lentil, and 2627.9 ha of sugarcane, with total projected net return of Rs 723,334,338.65.

The structure of this result mirrors the internal logic of the model. Sugarcane dominates because it offers the highest net return among the feasible activities, while arhar and lentil remain because pulse cultivation is both profitable and useful for satisfying the legume requirement. The disappearance of common paddy and wheat therefore should be read as a direct consequence of the baseline parameterization rather than as a rhetorical claim about their agronomic irrelevance.

C. What the Result Means Economically

The crop plan generated by the model points toward a more commercialized and value-oriented agricultural system than the one currently observed. Sugarcane emerges because of its high modeled return per hectare, while pulses gain importance because their prices and costs compare favorably with those of cereals. The result does not mean that cereals have no role in local farming. Rather, it shows that under the accounting structure of the model, they are not the income-maximizing use of land once more profitable alternatives are available.

This distinction matters. An optimization model is not a normative statement that staple crops are unnecessary; it is a diagnostic tool that identifies where the largest economic gaps lie. In this case, the model indicates that the largest forgone earnings are associated with the continued dominance of crops whose relative profitability is lower than that of available alternatives.

5. Discussion

A. Infrastructure as the Missing Link

The contrast between the optimized and observed crop pat terns should not be explained simply by assuming that farmers are conservative or inefficient. A more credible interpretation is that the local agricultural economy may not yet provide the institutional conditions needed to support the model's recommended crop mix. This interpretation is consistent with the broader literature on technology and practice adoption in developing-country agriculture, which shows that farmer decisions are shaped by market access, risk, liquidity, and institutional support rather than by technical profitability alone [10], [11].

Sugarcane is the clearest example. Large-scale cane cultivation requires reliable transport, timely harvesting, and access to crushing capacity. In the absence of proximate mills or dependable procurement, the crop becomes considerably riskier than the deterministic LP result suggests. A similar logic applies to pulses. Expanding pulse area is meaningful only if aggregation, storage, grading, and milling systems exist to translate field output into stable realized income. Without these facilities, higher modeled returns may not be captured by farmers. Because the paper does not independently measure these downstream constraints, the infrastructure explanation should be read as an interpretation consistent with the optimization gap, not as a directly estimated causal result.

That interpretation is also consistent with the structure of the baseline optimization itself, which assumes market clearance at stated prices and therefore does not directly model the processing and market support that would be required if sugarcane and pulse expansion were scaled in practice.

The same point applies to food security and risk. The baseline solution shows what profitability alone prefers when no positive food-grain minimum is imposed and when interannual uncertainty is absent. Actual farmers, by contrast, operate under food needs, uneven procurement assurance, and yield-price risk. The distance between the model outcome and present practice is therefore best understood as a substantive economic result: the current farming system reflects constraints and objectives that lie outside the narrow deterministic profit criterion.

B. Why Farmers Remain in the Rice-Wheat System

The persistence of paddy and wheat is therefore understandable. These crops are embedded in an established production and marketing environment. Inputs are familiar, the cultivation cycle is widely understood, procurement and selling channels are comparatively clearer, and the risk profile is socially known. Such conditions can make a lower-return crop economically rational from the perspective of a risk-averse household. This is consistent with the broader argument that diversification and innovation are often constrained by the surrounding institutional environment, not merely by technical awareness [10], [12].

C. Planning Implications

For local planning, the central lesson is that crop optimization should be linked to infrastructure planning. If the goal is to improve farm incomes in Jagdishpur through diversification toward higher-value crops, then investment is needed in procurement systems, transport networks, storage, processing, and farmer aggregation mechanisms. In the specific context of the current solution, sugarcane expansion would require access to crushing infrastructure, while pulse expansion would require local or regional milling and market-support facilities.

The result also suggests a sequencing logic for policy. Before urging farmers to shift strongly away from cereals, planners should assess whether the downstream market architecture is capable of absorbing and rewarding such a change. Otherwise, the optimized allocation remains an analytical upper bound rather than a feasible transition pathway.

D. Limitations

The present model is intentionally simple and should be interpreted accordingly. It does not represent price variability, market saturation, groundwater depletion, or household food-security preferences in a fully dynamic manner. It also abstracts from credit constraints and working-capital needs, which are often critical in crop choice. These omissions do not invalidate the optimization result, but they do limit its direct policy transferability. Future work should therefore combine LP-based planning with risk analysis, irrigation constraints, value-chain diagnostics, and where possible direct evidence on market access and processing capacity.

5. Discussion

This paper used a linear programming model to estimate the profit-maximizing crop allocation for Jagdishpur Block, Bihar. The optimized solution increases projected annual net return from Rs 40.92 crore to Rs 72.33 crore, largely through sugarcane and pulse expansion. The magnitude of the increase indicates that a substantial income gap separates the observed crop pattern from the mathematical optimum implied by current technical and price parameters.

At the same time, the study shows that this income gap can not be understood only as a production problem. It is equally a question of infrastructure and institutions. For block-level agricultural planning, optimization can identify promising directions for crop diversification, but implementation depends on whether processing, procurement, storage, and market-support systems are capable of sustaining the recommended shift. The practical value of LP-based crop planning therefore lies in combining resource optimization with a realistic assessment of the value chain through which farmers actually realize income.

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