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MICHIGAN STATE UNIVERSITY

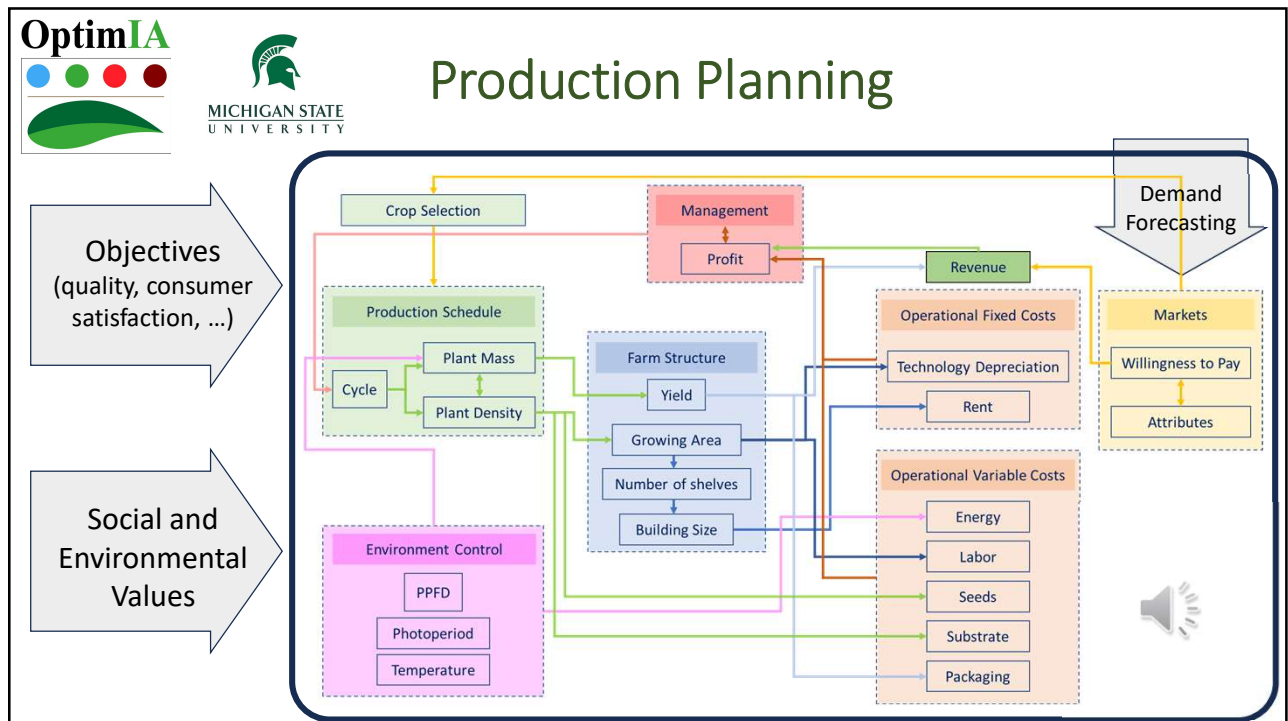
Economics of Indoor Agriculture Planning Production Efficiency

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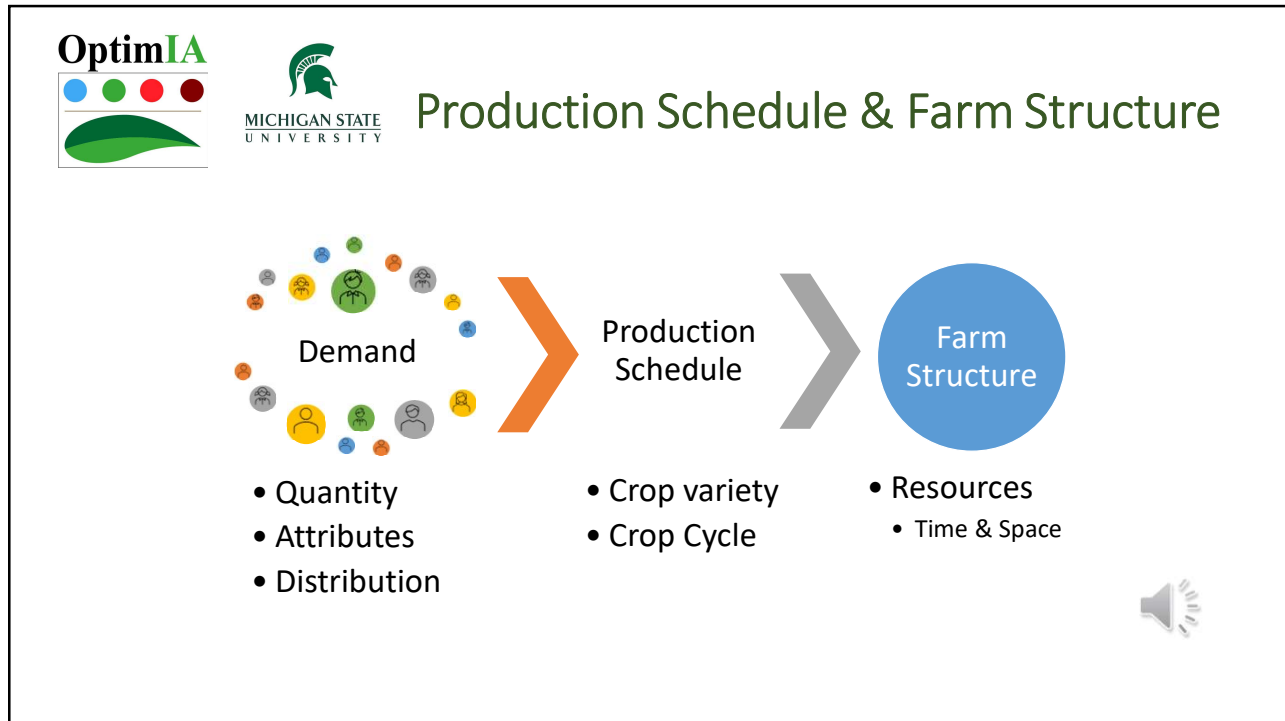
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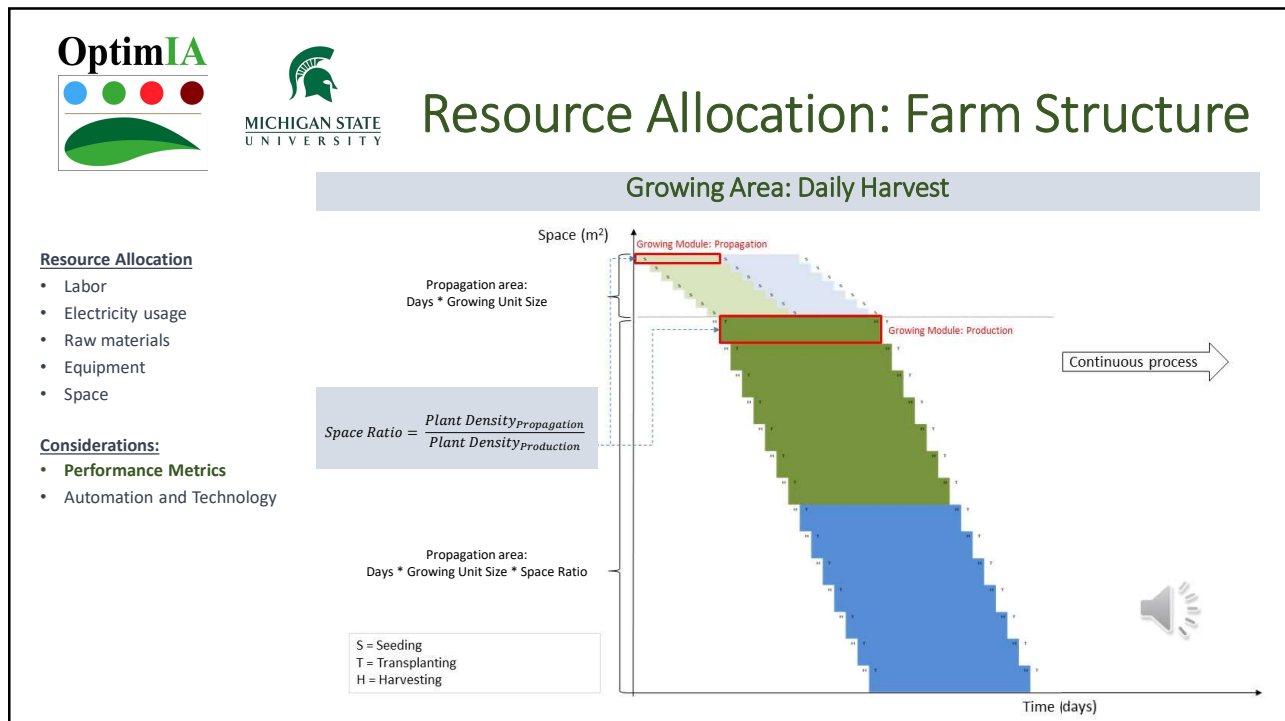
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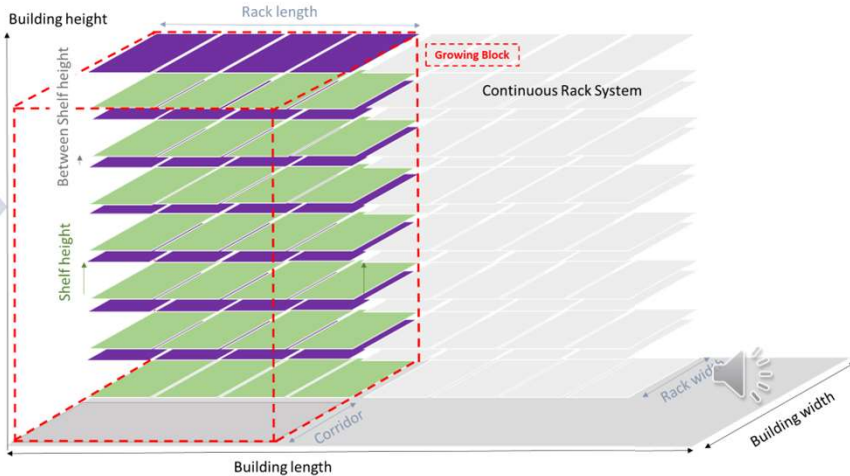



Resource Allocation in Vertical Farms: Thinking within the box



$$\text{Floor Area}_i = \frac{\text{Growing Area}_i}{\text{Levels}_i} + \text{Corridor Space}_i$$

i -> Propagation or Production Growing Area

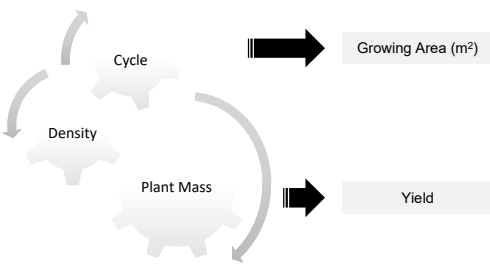
Note: Total building area will include space dedicated to power units, HVAC units, preparation, pre-cooling, shipping, offices, shower room, waste storage, etc.

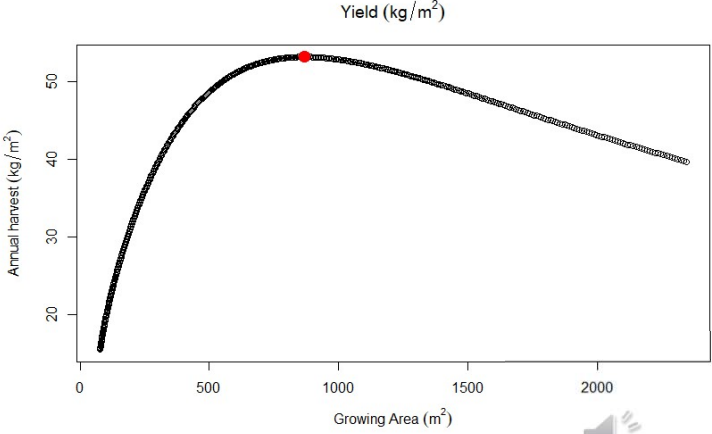


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Alternative Production Systems





Max Yield = 53 kg/m²
Growing area = 868 m²

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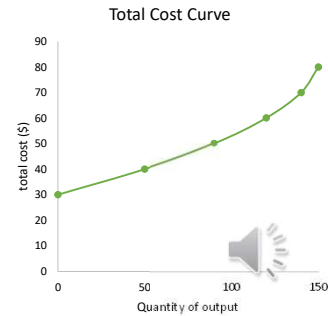
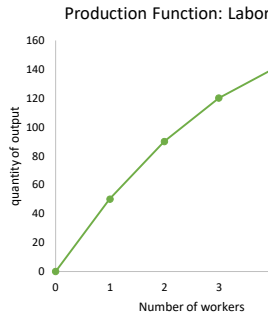


Planning Production: Production Function

Production Function: the relationship between the quantity of inputs required for a quantity of output.

Diminishing Marginal Product: the marginal product of an input declines as quantity of the input increases.

Number of workers	Output	Marginal output	Cost of farm (\$)	Cost of workers (\$)	Total cost of inputs (farm + workers) (\$)
0	0	-	30	0	30
1	50	50	30	10	40
2	90	40	30	20	50
3	120	30	30	30	60
4	140	20	30	40	70
5	150	10	30	50	80

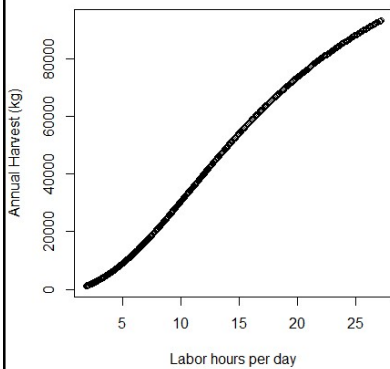


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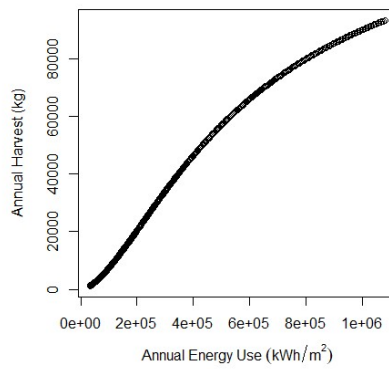


Production Function: Labor and Energy

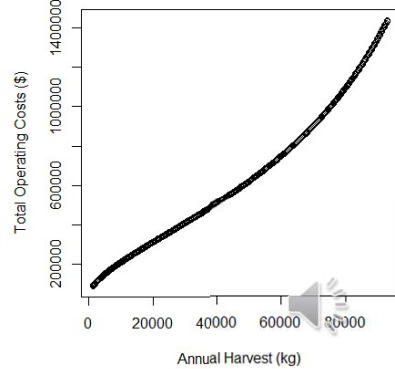
Production Function: Labor





Production Function: Energy



Total Cost Curve in an Indoor Farm

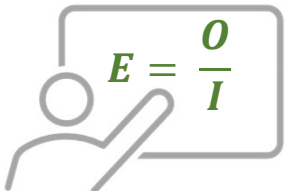


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Efficiency

The ratio of total output to total input



Input:

↓

Resources
Time
Space

Efficiency ratios determine how productively a farm uses resources and investments:

- Relative to the operation
 - Technological investments
 - Improved production processes
 - Costs and resource utilization
 - Investments
- Relative to the industry
 - Competitive advantage
 - Industry growth



Output:

↑

Sustainability
Profit
Yield

← Quality, Consumer satisfaction, Social and Environmental Values →



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Efficiency Considerations

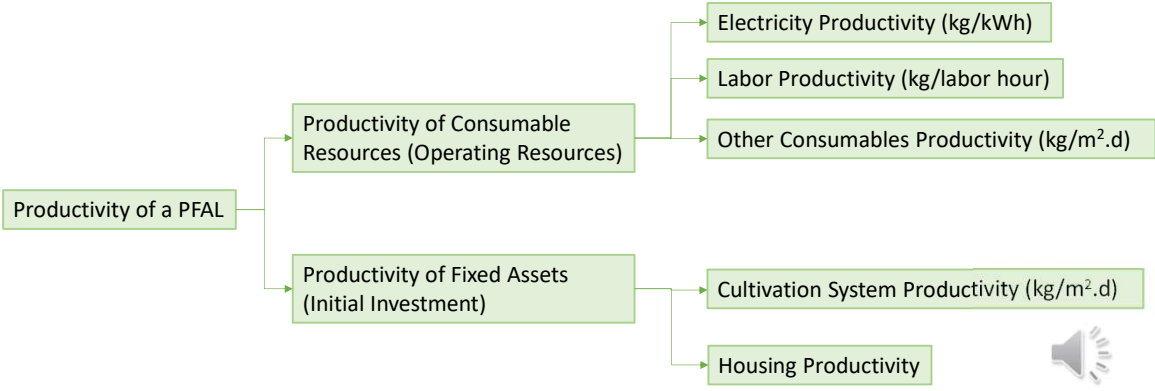
Resource Allocation	<ul style="list-style-type: none"> Labor, raw materials, equipment, and space to ensure optimal utilization and minimal wastage.
Lean Principles	<ul style="list-style-type: none"> Eliminate waste, reduce production time, and improve overall process efficiency (i.e., Value-added focus, Kaizen, Pull system)
Automation and Technology	<ul style="list-style-type: none"> Integrate technology and automation where applicable
Quality Control	<ul style="list-style-type: none"> To ensure that products meet the required standards and minimize defects or rework
Inventory Management	<ul style="list-style-type: none"> To avoid overstocking or stockouts, thus optimizing working capital
Continuous Improvement	<ul style="list-style-type: none"> Encouraging feedback, analyzing data, and making necessary adjustments to enhance efficiency over time
Risk Management	<ul style="list-style-type: none"> Potential risks that could disrupt production efficiency and develop contingency plans to mitigate these risks

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Measuring Production Efficiency

Performance Metrics: Define key performance indicators (KPIs) to measure and evaluate the success of production efficiency initiatives.





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graph LR
    A[Productivity of a PFAL] --> B[Productivity of Consumable Resources (Operating Resources)]
    A --> C[Productivity of Fixed Assets (Initial Investment)]
    B --> D[Electricity Productivity (kg/kWh)]
    B --> E[Labor Productivity (kg/labor hour)]
    B --> F[Other Consumables Productivity (kg/m².d)]
    C --> G[Cultivation System Productivity (kg/m².d)]
    C --> H[Housing Productivity]
    
```

Source: Adapted from: Uraisami (2019) "SE06-07: How to integrate and to optimize productivity at PFALs". Copyright(C) 2019 Japan Plant Factory Association (NPO), and T. Kozai (ed.), Smart Plant Factory, Springer Nature Singapore Pte Ltd. 2018 https://doi.org/10.1007/978-981-13-1065-2_6

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KPI Examples

Index	Resource	Hypothetical Farm*	PFAL**
Resource Productivity	Energy use (kg/kWh)	0.12	0.11 – 0.14
	Labor hours (kg/hour)	9.5	7.7 – 10.0
Monetary Productivity	Energy use (kg/\$)	0.891	0.645 – 0.755
	Labor hours (kg/\$)	0.632	0.591 – 0.770
	Other resources (kg/\$)	0.881	0.609 – 0.827
Production Costs	Energy use (\$/kg)	1.22	1.09 – 1.28
	Labor hours (\$/kg)	1.58	1.18 – 1.63
	Other resources (\$/kg)	1.14	1.00 – 1.36
Production	Fresh weight (kg/m ² day)	0.147	0.148 – 0.293

* Results from a partial budget analysis using a model of a hypothetical vertical farm producing lettuce in the U.S.
 ** Results from alternative production schedule scenarios in a Japanese Plant Factory (Kozai, 2022)

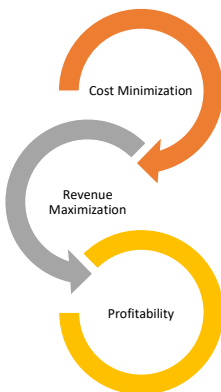
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Efficiency and Profitability

Managing Productivity Efficiency:

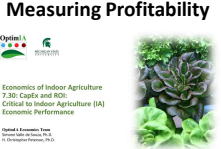
- Minimizing costs
 - Monetary productivity of inputs and resources
 - Targeting Economies of Scale
- Maximizing revenue
 - Meeting consumer demands
 - Exploring new niche market
 - Alternative distribution systems




Operating Costs



Measuring Profitability



Value Proposition



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Thank you!

Acknowledgement

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