Decision Support for Small-scale Vertical Farms

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(Farm.One, 2018)
Global Megatrends

- Increasing population (approx 10 billion by 2050)
- Water scarcity
- Deforestation
- Climate change
- Rapid urbanisation (66% living in cities by 2050)
- Food insecurity

Food Problems

- Steady decline of arable land per capita, 50% that it was in 1961.
- Will continue with global warming and deterioration of natural resources
- Agriculture contributes roughly 24% of global greenhouse gas emissions

Feeding the Future: Not Enough Land

(Despommier, 2009)
What is vertical farming?

- Hydroponics - soil-less... uses 90% less water!
- Cultivates plants indoors in vertical layers or inclined surfaces
- Artificial lighting
- Controlled environment - year round produce
- Protection from harsh weather phenomena
- Ideal for urban contexts - UF potential to feed 10%

Why?

- Local produce - tackles problems with mass distribution
- New skilled jobs
- Can convert underutilised buildings
- Access to healthier living
- Education of technology and agrifood
- City resilience

Industry has expanded rapidly in recent years

(Plenty, 2018)
The Integrated Urban Farming System
**Challenges**

- Difficulties predicting profitability margins
- High-risk endeavour
  - Pathogens and pests
  - Miscalculating costs
- High energy consumption
- Wide but scattered literature
- No standardisation and lack of aggregated data sources
- No decision support or policy for SMEs
- Requires evidence for environmental sustainability

**Key considerations:**

- Quality farm labour requires education
- Labour is a biggest cost
- Good location is critical
- Price on value
Decision Support System (DSS)

What can be done to facilitate sustainable growth?

Currently there are no publicly available DSSs for VFs - although used in academia for hydroponics and greenhouses since 1990s.

A means to formalise expert practice and scientific knowledge
Tool Kit

- Decision support to improve VF planning and operations
- Costs calculator
- Utilise cutting-edge research
- Open-source
- Economic forecast
- Monte Carlo analysis
- Global adaptability
- Environmental impacts
- Cost-benefit analyses
❖ Graphic User Interface

Allows the user to navigate to:

- User decisions
- Analyses
- Solutions

Key:

- Yellow box - calculations based on user-inputs
- ‘i’ for further information
- Shaded text - default values (should be changed)
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❖ Graphic User Interface

Software allows self-documentation of input files to record:

- Double click any field
- Linguistic data inputs
- Description of the variable units
- Who characterised an uncertain number
- The nature of the estimate or observation
- What the reason or argument was
- The relevant references
- What the supporting data are
Risk of Bankruptcy

- Propagating measurement error for capital costs
- Propagating temporal variability for revenue projections and operating costs

Adapted from (Ferson, 2000)
Risk of Bankruptcy

- Stochasticity introduced from:
  - user-inputs and associated uncertainties
  - risks based on management practices, reviewed through case studies and surveys
- First passage time - records when simulation hits determined threshold
- Monte Carlo analysis to estimate insolvency probability

Adapted from (Ferson, 2000)
Risk of Bankruptcy

User can:
- run scenarios and visualise a deterministic projections, with associated timelines
- see a breakdown of risks occurring
- select mitigation strategies and consequently see improved risk profile
Risk of Bankruptcy

Risk assessment graph depicts levels of threat as a function of time and probability of bankruptcy.

- **Critical**: 50% probability of bankruptcy in 3 years
- **Substantial risk**: 25% probability of bankruptcy within 5 years
- **Moderate risk**: 10% probability of bankruptcy in 10 years
- **Safe**: Less than 10% probability of bankruptcy within 10 years

Adapted from (Akcakaya, 2000)
Sustainometrics

Radar chart comparison normalised to baseline data.

Crop productivity per:
- unit litre of water
- unit watt of power
- unit sq-m of growing area
- unit cb-m of growing volume
- unit of man-hour of labour
- unit litre of nutrients

Based on Sustainability framework from Association of Vertical Farming.
Currently collecting data

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A carbon-footprint model that enables vertical farmers to understand their environmental impact.

Encourages and drives change to be environmentally sustainable.

Options to introduce renewable energies to review carbon reductions with associated cost-benefit analysis.
Conclusions & Future Works

Conclusions

- Need for economic and environmental analysis should be delivered in a decision tool
- Scattered and diverse literature will inform calculations and design on DSS

Future Works:

- Survey vertical farms for key risks and economical data
- Program calculators and embedded models
- Checklists for management practices
- Case studies on risk mitigation, environmental solutions and best management practices
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Thank you for listening
Any questions?