Application of Portfolio Theory to Support Resource Allocation Decisions for Biosecurity

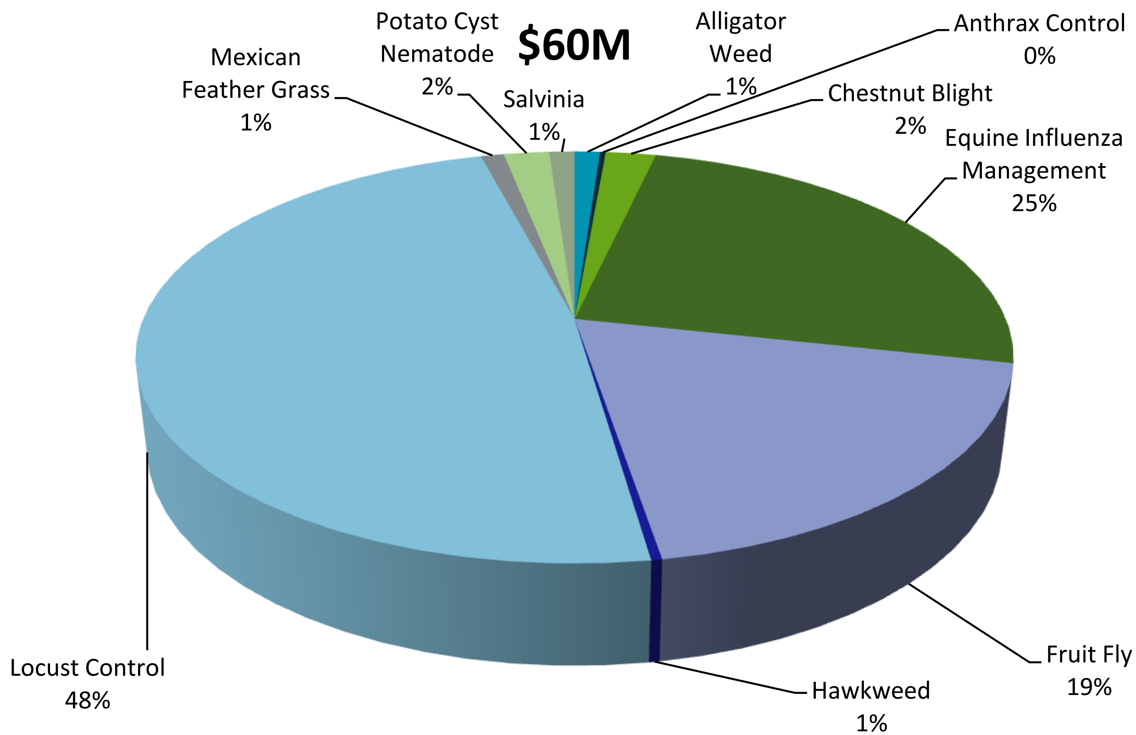
Paul Mwebaze | Economist

11 September 2013

Presentation outline

- The resource allocation problem
- What can economics contribute?
- Portfolio theory
- Biosecurity applications
- Empirical model: Hypothetical surveillance problem
- Preliminary results: portfolio optimisation
- Conclusion and next steps...

How much to spend on different threats?



Source: DPI (2012). Biosecurity incidents in Victoria 2007-2011

What can economics contribute?

- Economics is about the scarcity of resources and how to allocate the available resources in the best possible way to maximise objectives set by the decision maker.

- A number of tools available from economics and decision science (Rich et al., 2005);
  - Cost-benefit analysis (Boardman et al. 2006)
  - Portfolio theory (Markowitz, 1952)
  - Linear programming and optimisation
  - Search theory/economics for optimum surveillance
  - Bio-economic models etc

Portfolio Theory (Markowitz, 1952)

- Portfolio theory emerged to address the problem of finding the portfolios that maximise expected return on investment while minimising risk (Markowitz, 1952).
- Key variables are expected mean return and risk, the latter is measured using standard deviation.
- Widely used in the financial industry to select combinations of financial instruments (stocks, bonds, treasury bills etc).
- Concepts of portfolio theory are applicable to other projects (Prattley et al., 2007)

Application to other projects

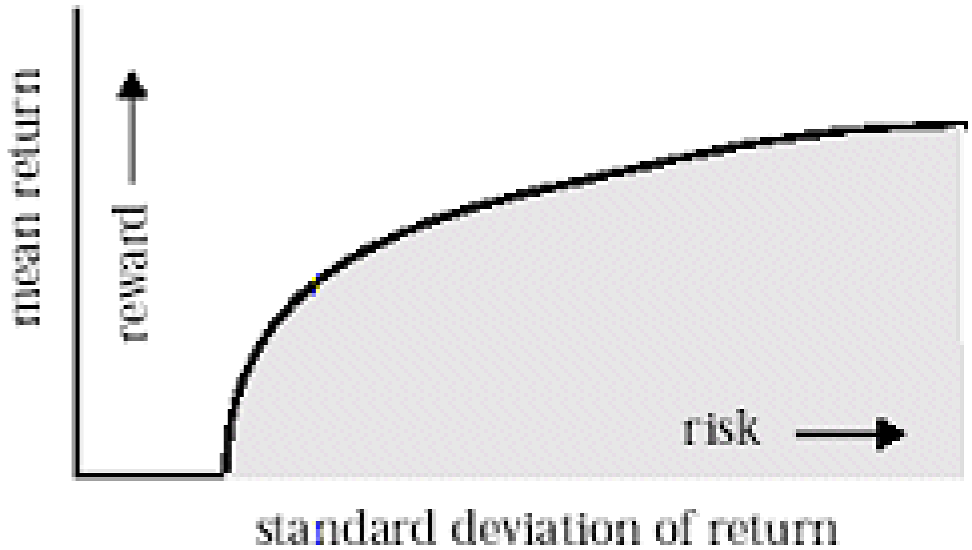
- Gaydon et al. (2012). (Agricultural Water Management). Comparing water options for irrigation farmers using portfolio theory.

- Prattley et al. (2007). (Preventive Veterinary Medicine). Application of portfolio theory to risk-based allocation of surveillance resources in animal populations in New Zealand.

- Bridges J (2004). (Health, Risk & Society). Understanding the risks associated with resource allocation decisions in health: An illustration of the importance of portfolio theory.

- Galligan D.T, Marsh W.E. (1988). (preventive veterinary medicine). Application of portfolio theory for the optimal choice of diary veterinary management programs.

The Efficient Frontier (Markowitz, 1991)



• A portfolio lying on the efficient frontier shows the combination offering the best Possible expected return for a given level of risk.

Portfolio Characteristics: Expected return and risk (standard deviation)

$$E(R_p) = \sum_{i=1}^{n} w_i E(R_i) \qquad (1)$$

$$\sigma_p = \left[\sum_{i=1}^{n} (w_i^{\,2} \sigma_i^{\,2}) + \sum_{i=1}^{n} \sum_{j=1}^{n} (w_i w_j \sigma_i \sigma_j \rho_{ij}) \right]^{1/2} \qquad (2)$$

$$\sigma_p = \left[\sum_{i=1}^{n} \sum_{j=1}^{n} (w_i w_j \sigma_i \sigma_j \rho_{ij}) \right]^{1/2} \qquad (3)$$

R_p is expected return on the portfolio, R_i is expected return on asset i, w_i is the weight or share of asset i, ρ_{ij} is the covariance between returns on asset i and asset j

The Portfolio Choice Theorem

$$Max \quad f(w)$$

$$f(w) = \alpha_p - \frac{1}{2} A \sigma_p{}^2$$

$$= \sum_{i=1}^{n} w_i \alpha_i - \frac{1}{2} A \sum_{i=1}^{n} \sum_{j=1}^{n} w_i w_j \rho_{ij} \qquad (4)$$

$$subject\ to \quad \sum_{i=1}^{n} w_i = 1$$

n= number of assets,
w_i=proportion of portfolio invested in asset i,
α=expected return of asset i, α_p=expected return of portfolio, σ_p= standard deviation of portfolio
ρ= covariance of asset i with asset j, A=coefficient of relative risk aversion

Example: Hypothetical surveillance problem

Investment areas	Annual rate of return	Lower bound	Upper bound
Pest A	3.0%	$0	$50,000
Pest B	5.0%	$10,000	$25,000
Disease C	7.0%	$0	$80,000
Disease D	11.0%	$10,000	$100,000

A decision maker is faced with a problem to allocate a surveillance budget of $100,000 to 4 biosecurity areas. The annual returns for each project and the minimum and maximum amounts the decision maker is comfortable allocating to each project are listed above. What is the best allocation strategy that results in the highest mean total expected return?

Portfolio optimisation

- The source of uncertainty in this problem is the expected annual return of each investment. So we need to create probability distributions that describe the uncertainty surrounding specific input variables?

- **The decision problem:** To determine how much to invest in each asset to maximise total expected returns while keeping the risk at an acceptable level and staying within the constraints and requirements.

- **Objective function:** Maximise the mean total expected return subject to a budget constraint.

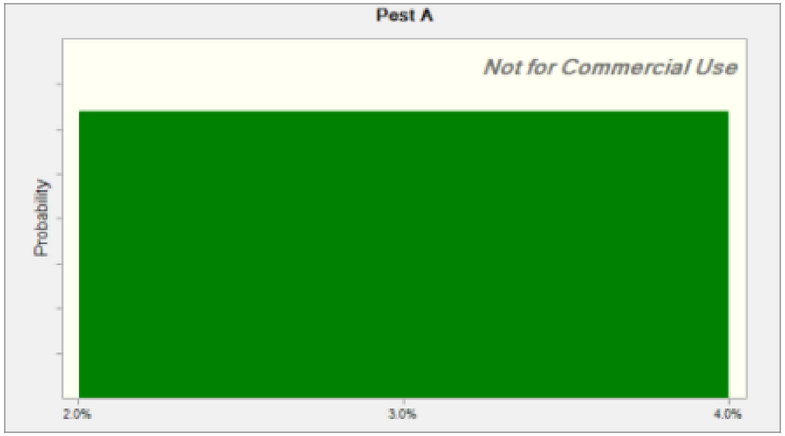
- **Constraint:** Linear budget constraint

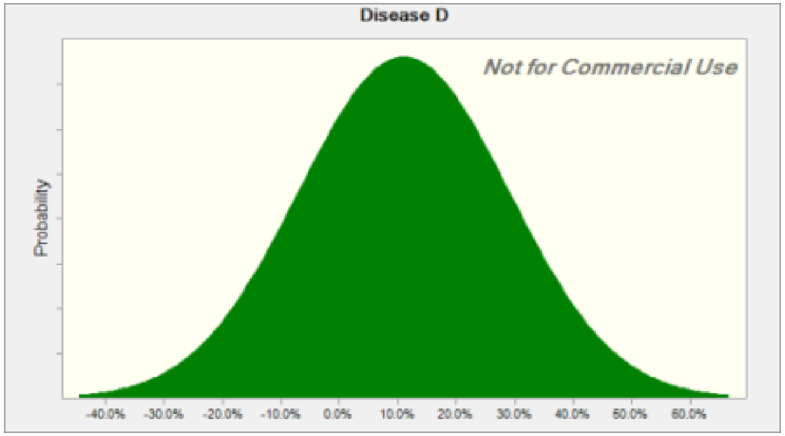
- **Requirements:** Lower bound and upper bound limits for decision variables.

- **Method:** Stochastic optimisation model (with Monte Carlo simulation)

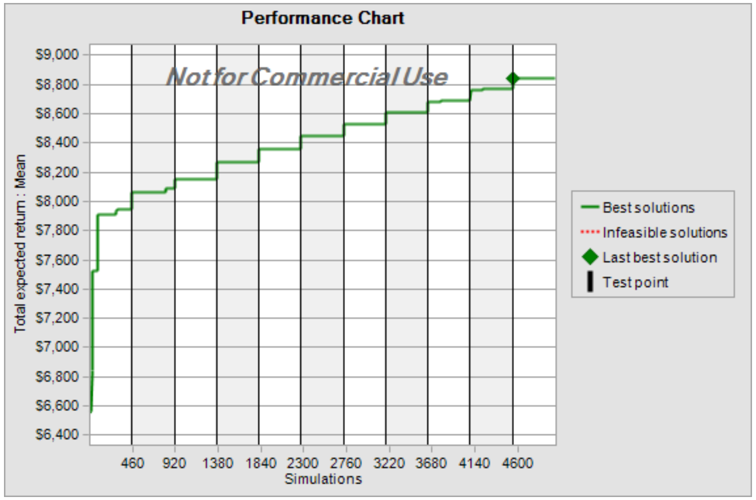
Model assumptions/probability distributions

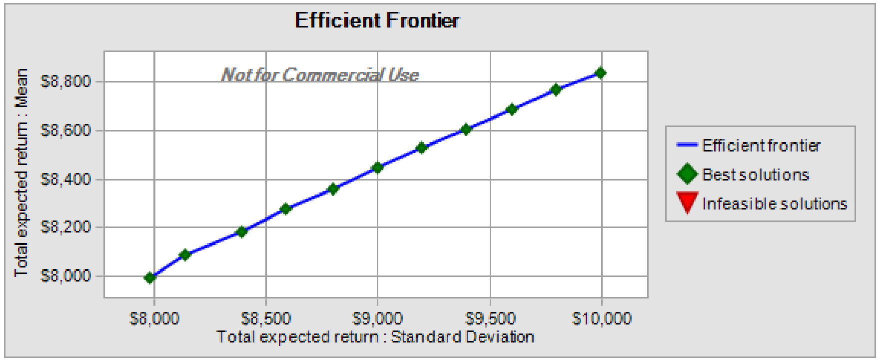
Investment areas	Annual rate of return
Pest A	3.0%
Pest B	5.0%
Disease C	7.0%
Disease D	11.0%





Portfolio optimisation (results)





Investment areas	Amount invested ($)	Share (%)
Disease C	$41,200	41%
Disease D	$48,400	46%
Pest A	$400	1%
Pest B	$12,000	12%

Conclusion and next steps

- "Behold, the fool saith, "Put not all thine eggs in the one basket" - which is but a matter of saying, "Scatter your money and your attention"; but the wise man saith, "Put all your eggs in the one basket and - WATCH THAT BASKET." – Mark Twain, in Pudd'nhead Wilson's Calendar, 1894"

- Additional modelling work in GAMS
  - Correlations
  - Risk aversion parameter
  - Develop 2 detailed case studies

Thank you

CES/Biosecurity Flagship
Paul Mwebaze
Research Scientist

t +61 7 3383 5613
e Paul.Mwebaze@csiro.au
w www.csiro.au/lorem

CSIRO