MODELING ECONOMIC-ENVIRONMENTAL TRADE-OFFS USING SAFETY-FIRST CONSTRAINTS

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INTRODUCTION

- Decision makers aim to improve production income
- Risk reducing nature of fertiliser will lead to increased fertiliser use
- Optimal resource allocation is important not only because of its effects on farm income but also due to its effect on environmental health
- No market exists for environmental health
- Trade-off curves show the reductions in residuals or the environmental variable and the associated reduction in farm income as abatement efforts require lower emissions

OBJECTIVE

- Integrated analyses of the impact of nitrogen fertiliser applications on production risk and the environment
  - to determine how the presence of an environmental constraint will affect the risk efficiency of production
  - to estimate the cost of compliance faced by risk averse decision makers for increasing levels of assurance
  - to determine how decision makers will achieve compliance

- The novelty of the approach is that both production risk and environmental risk are characterised by a continuous empirical representation of these risks.
- Through the use of the response functions a clear link is created between the source of the pollutant, the production risk stemming from its use and the environmental outcome.

DATA

- SWB_Sci was used to simulate production data and the environmental indicator (N runoff and leached)
- Late monoculture maize (planting date 15 December) under irrigation on a sandy clay loam (SCL) and a sandy clay (SC) soil at Glen, South Africa
- No water stress
- 19 different weather years
- Nine levels of nitrogen fertiliser were applied, in either a single or a split application
- Assuming an initial soil nitrogen level of 33kg

- Crop yield and irrigation water response functions were estimated for every production year based on the decision makers' fertiliser use decision.
- Nitrate loss response functions were estimated using the simulated environmental indicator

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DETERMINING THE BASELINE

- Producers typically do not consider the environment when making fertiliser application decisions
- Optimal fertiliser level endogenously determined based on all possible outcomes in all states of nature and the probability of occurrence
- Nitrate losses of all four alternatives were averaged to determine a homogenous environmental goal of 28 kg/ha.

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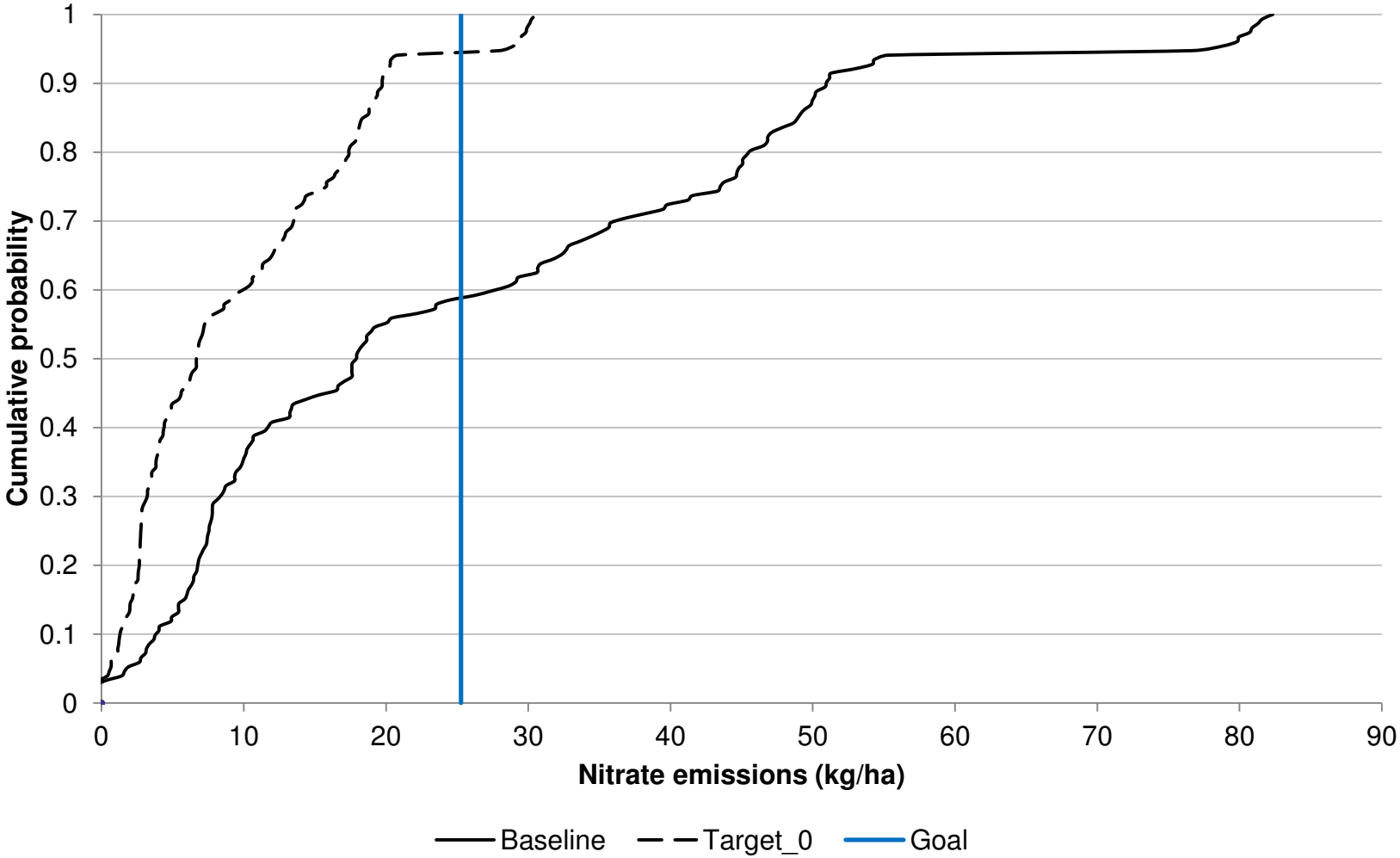
UPPER PARTIAL MOMENT

- A method to impose a probabilistic constraint using the Target-MOTAD framework
  - Empirical distribution of the outcome variable.
- UPM is useful to model safety-first behaviour
  - Safety-first behaviour is defined as behaviour in which the probability of failing to achieve a goal impacts and constraints the activities undertaken

Cumulative probability density function for emissions for unconstraint production and constraint production on a SCL soil with a Single application of nitrogen fertiliser



RISK EFFICIENCY OF FERTILISER USE

- Constrained model is solved for a user-specified environmental goal of 28kg/ha
- Compliance probabilities of 0.6, 0.7 and 0.8.
- The risk efficiency frontier consists of the optimal risk portfolio for the decision maker, based on the highest estimated CE.

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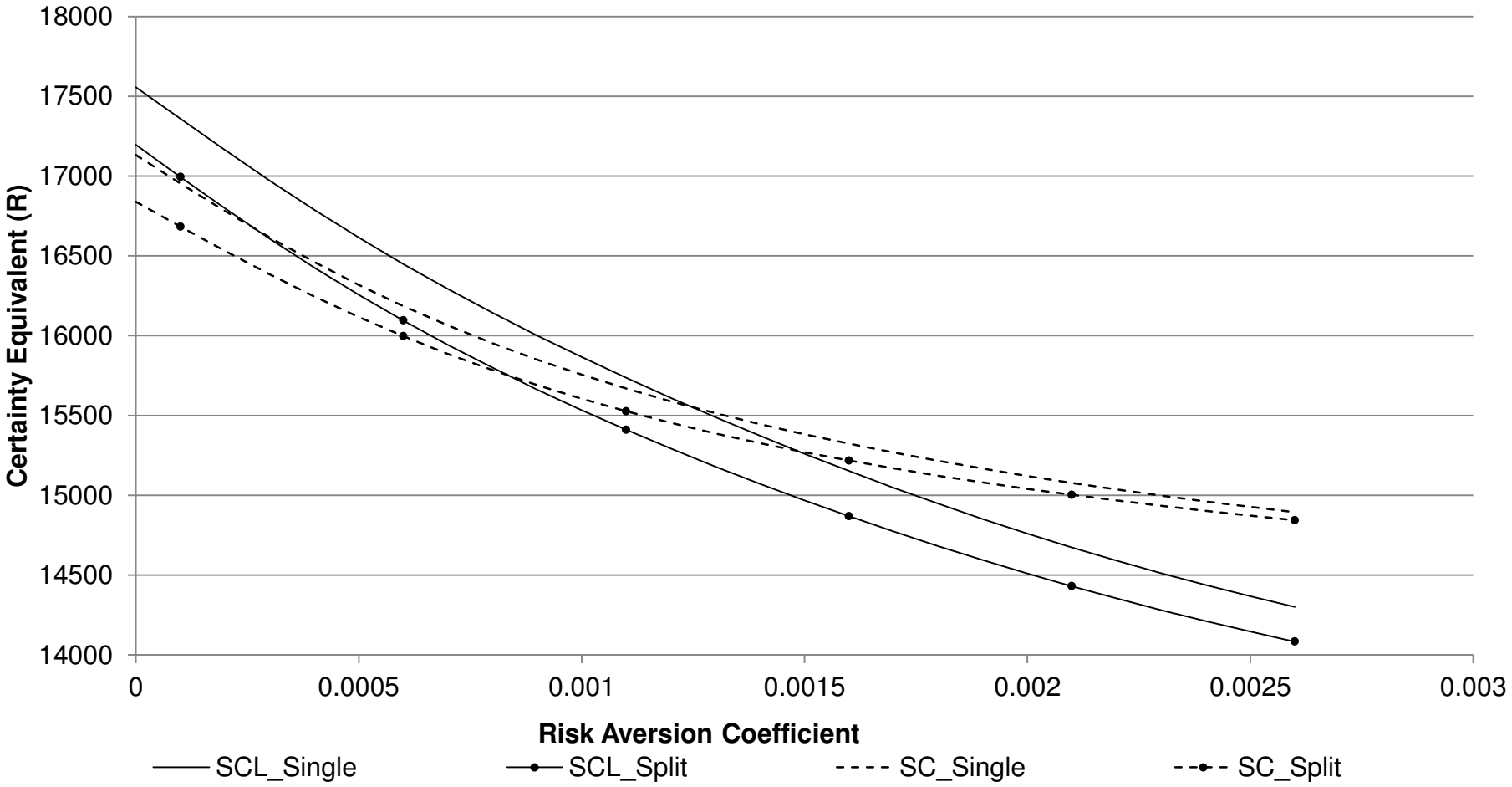
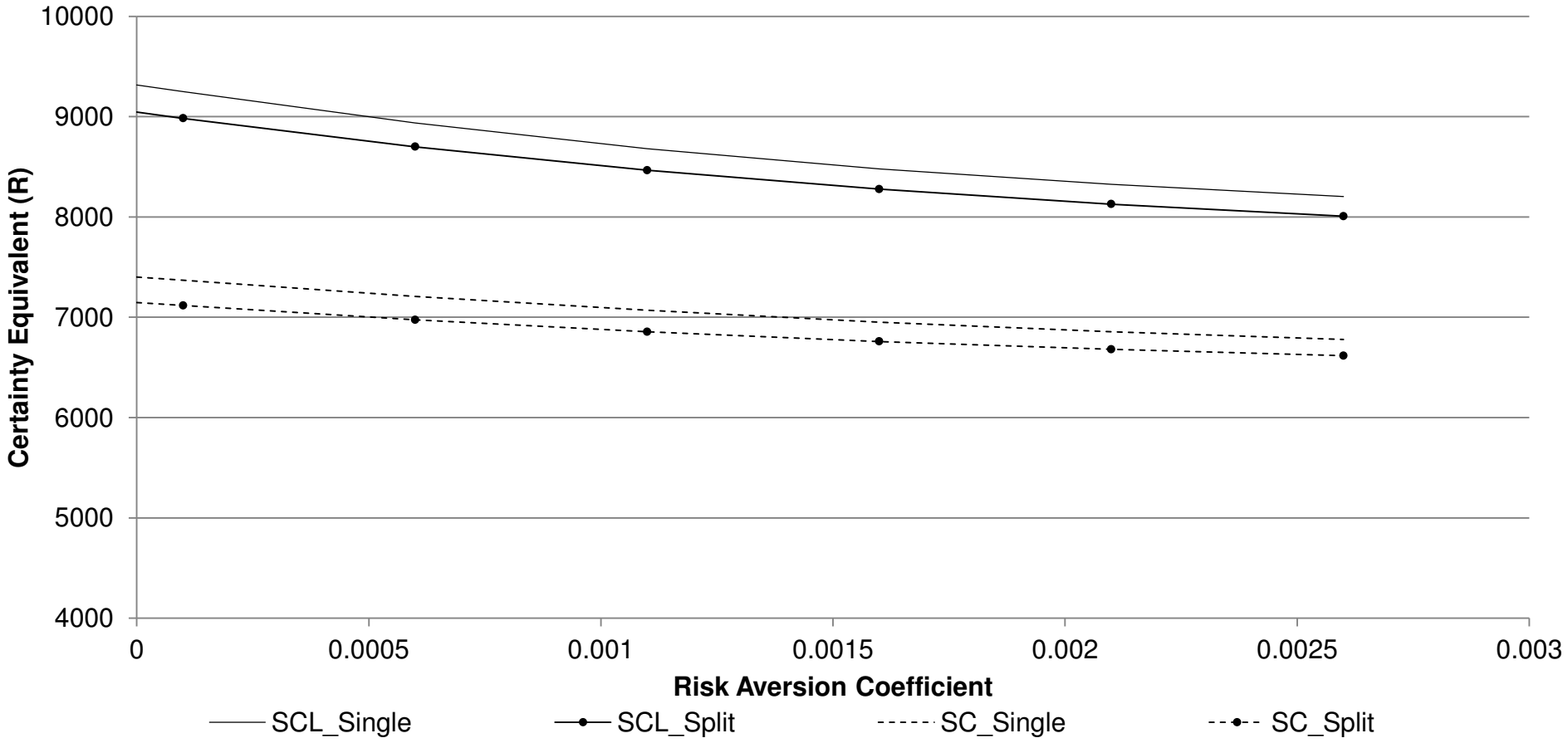
ESTIMATED CERTAINTY EQUIVALENT (CE IN R INCREASED RISK AVERSION (RAC) FOR COMPLIANCE TO AN ENVIRONMENTAL GOAL OF 28KG/HA.



Unconstraint

ESTIMATED CERTAINTY EQUIVALENT (CE IN R INCREASED RISK AVERSION (RAC) FOR COMPLIANCE TO AN ENVIRONMENTAL GOAL OF 28KG/HA.



Compliance 0.6

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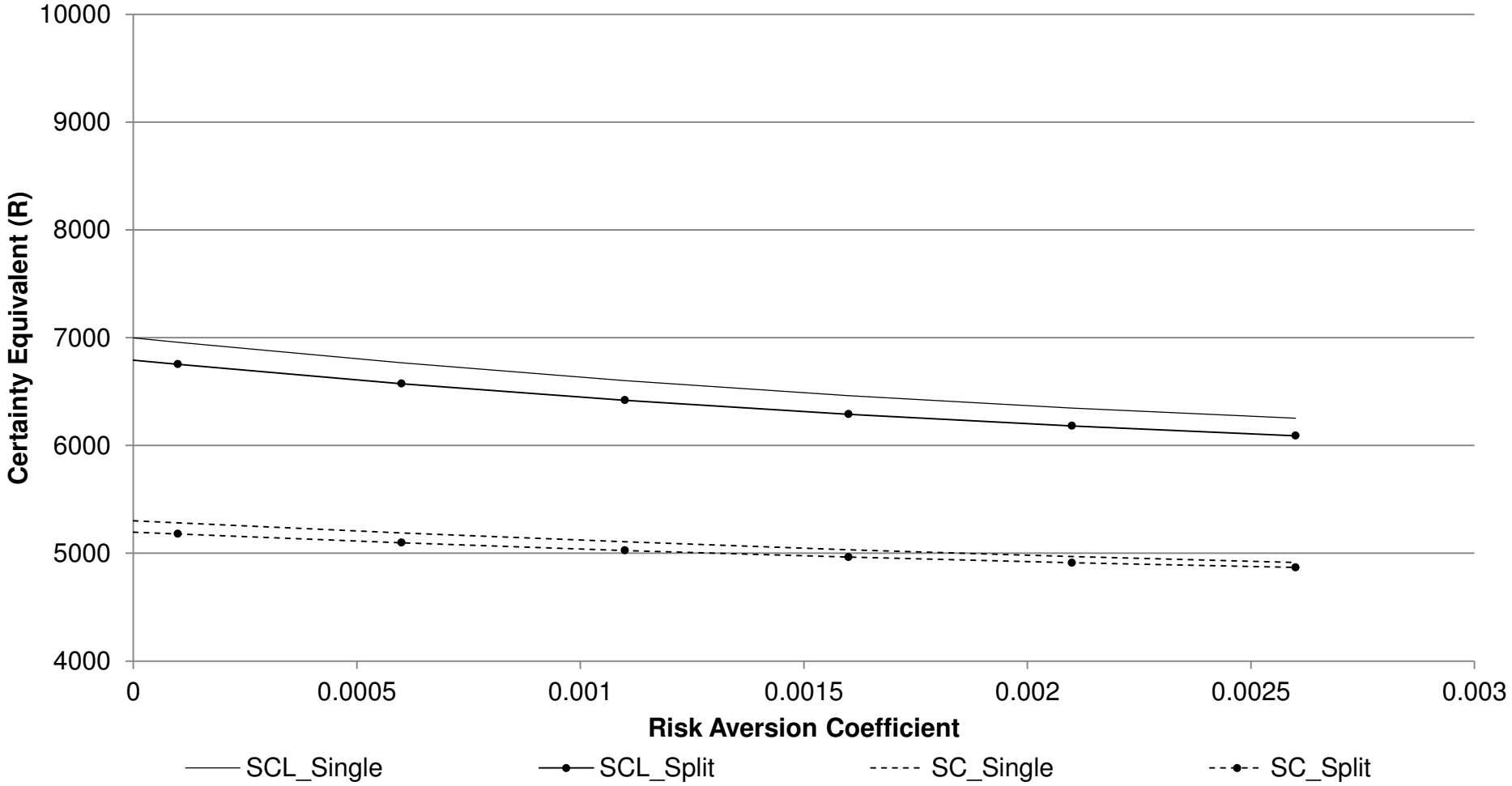

Compliance 0.8

COST OF ENVIRONMENTAL COMPLIANCE

- The cost of compliance is estimated as the difference between the certainty equivalent for a base scenario (CE_B) and the estimated certainty equivalent for an alternative scenario (CE_A).
- Estimation of the cost of compliance requires knowledge of a base scenario and an alternative scenario.
- The estimation of cost of compliance is therefore specific for each soil type and fertiliser application method

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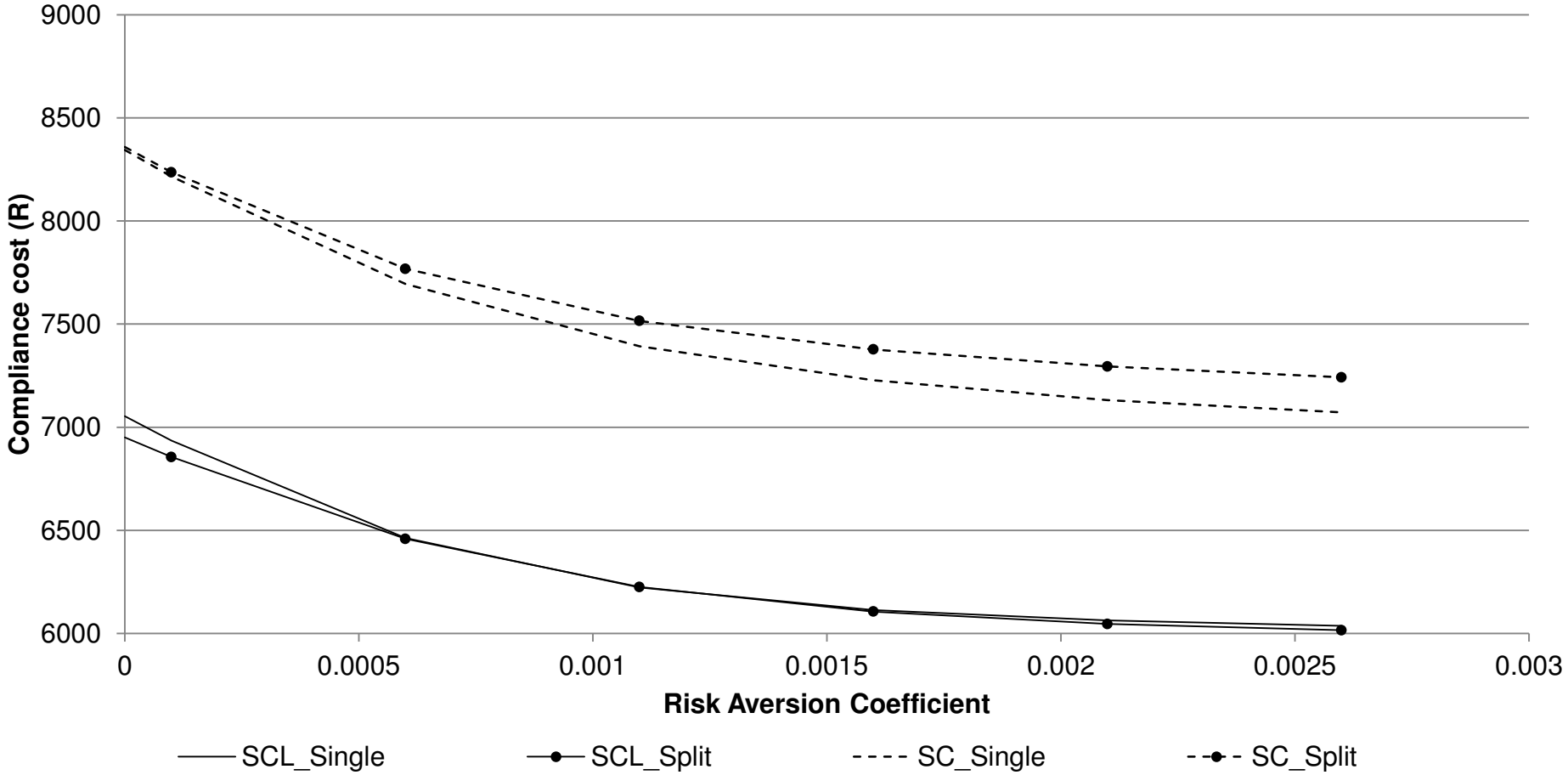
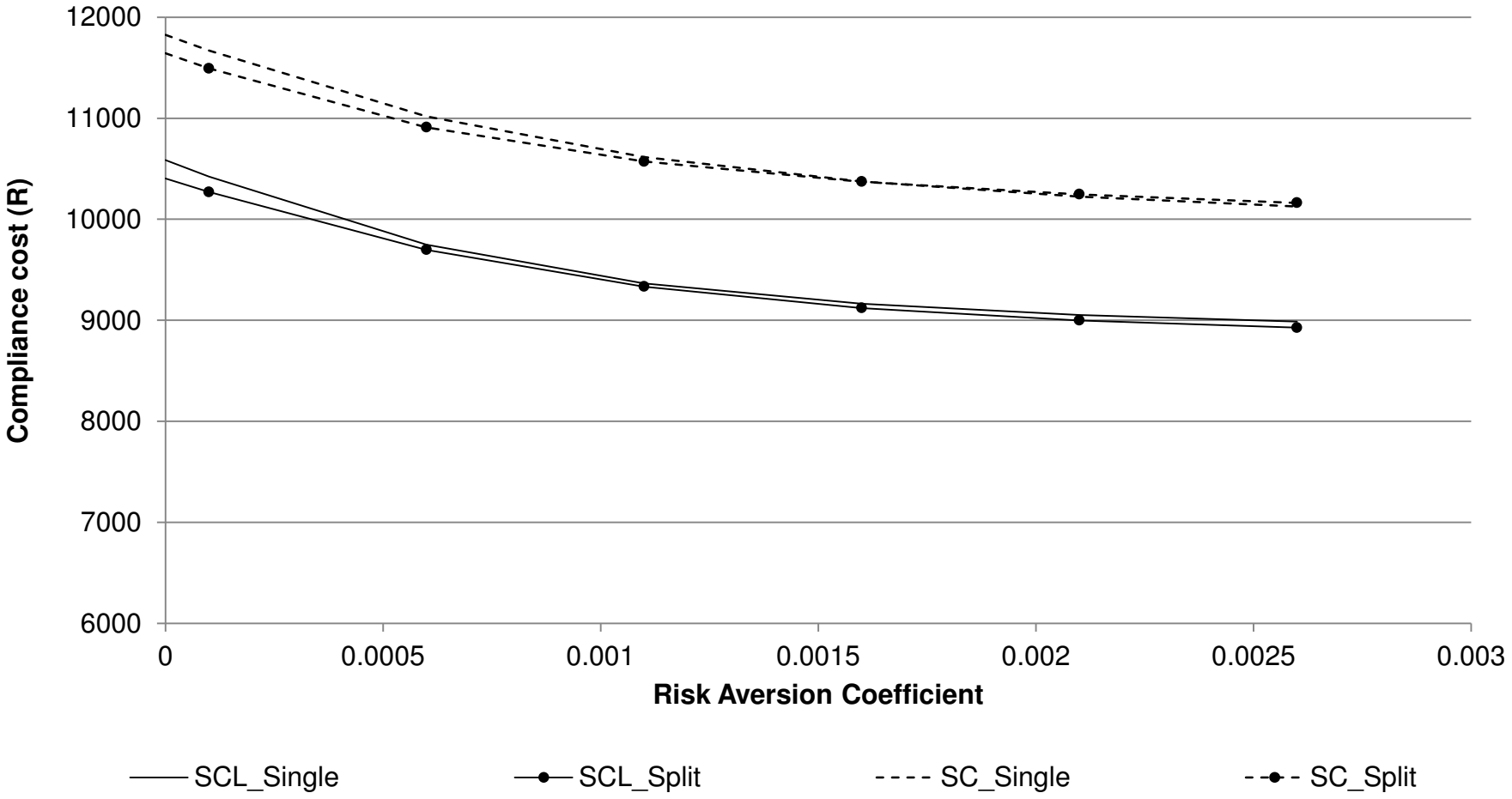
ESTIMATED RISK PREMIUM (RP IN R) FOR INCREASED RISK AVERSION (RAC) FOR COMPLIANCE TO AN ENVIRONMENTAL GOAL OF 28KG/HA FOR FOUR COMPLIANCE PROBABILITIES



Compliance 0.5

ESTIMATED RISK PREMIUM (RP IN R) FOR INCREASED RISK AVERSION (RAC) FOR COMPLIANCE TO AN ENVIRONMENTAL GOAL OF 28KG/HA FOR FOUR COMPLIANCE PROBABILITIES



PRODUCTION DECISIONS TO ENSURE COMPLIANCE

- Compliance to the environmental constraint requires that decision makers change their production practices.

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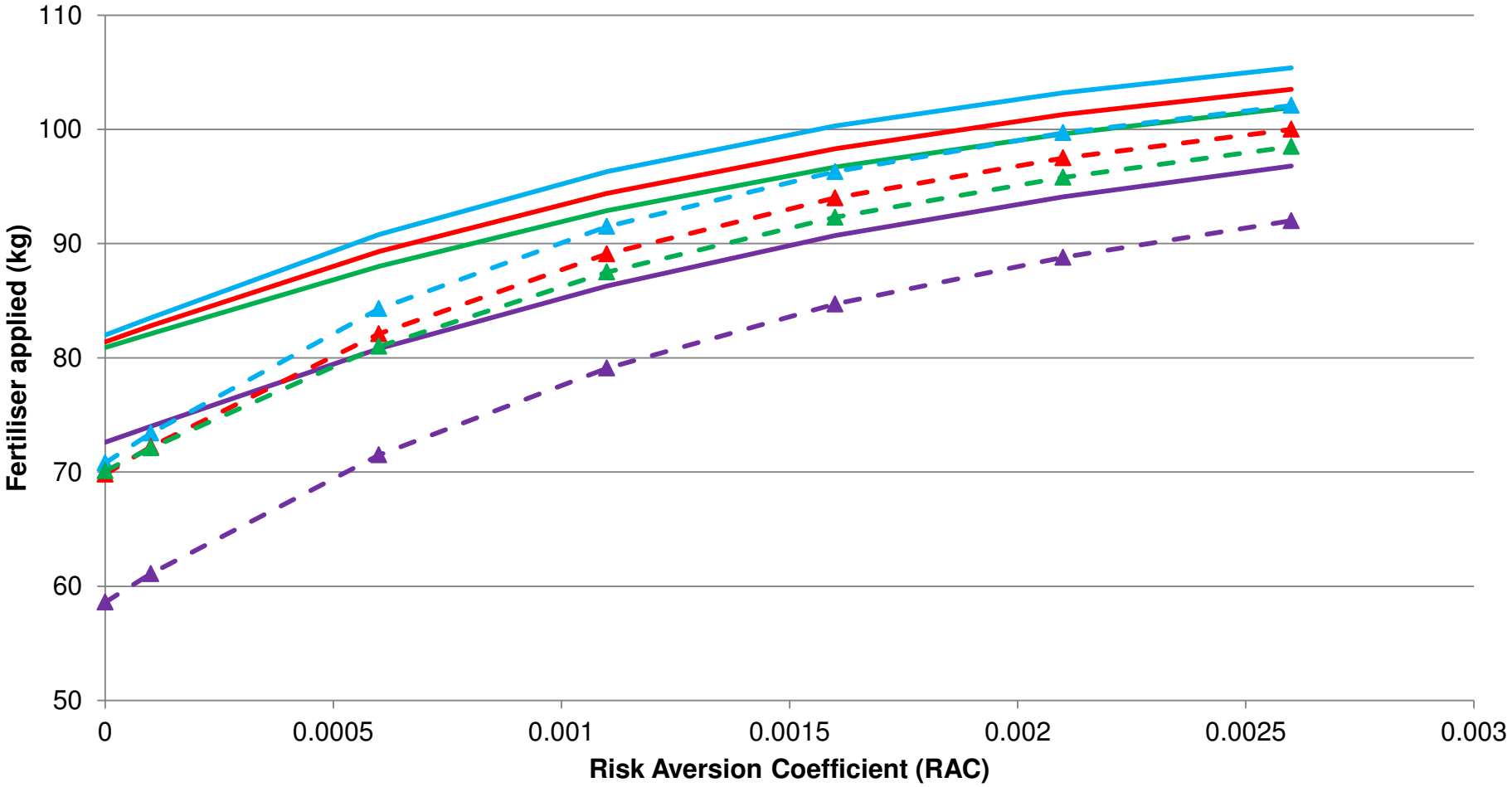
FERTILISER APPLICATION ON A SANDY CLAY LOAM SOIL FOR A SINGLE AND SPLIT APPLICATION FOR INCREASED RISK AVERSION (RAC) FOR COMPLIANCE TO AN ENVIRONMENTAL GOAL OF 28KG/HA FOR FOUR COMPLIANCE PROBABILITIES



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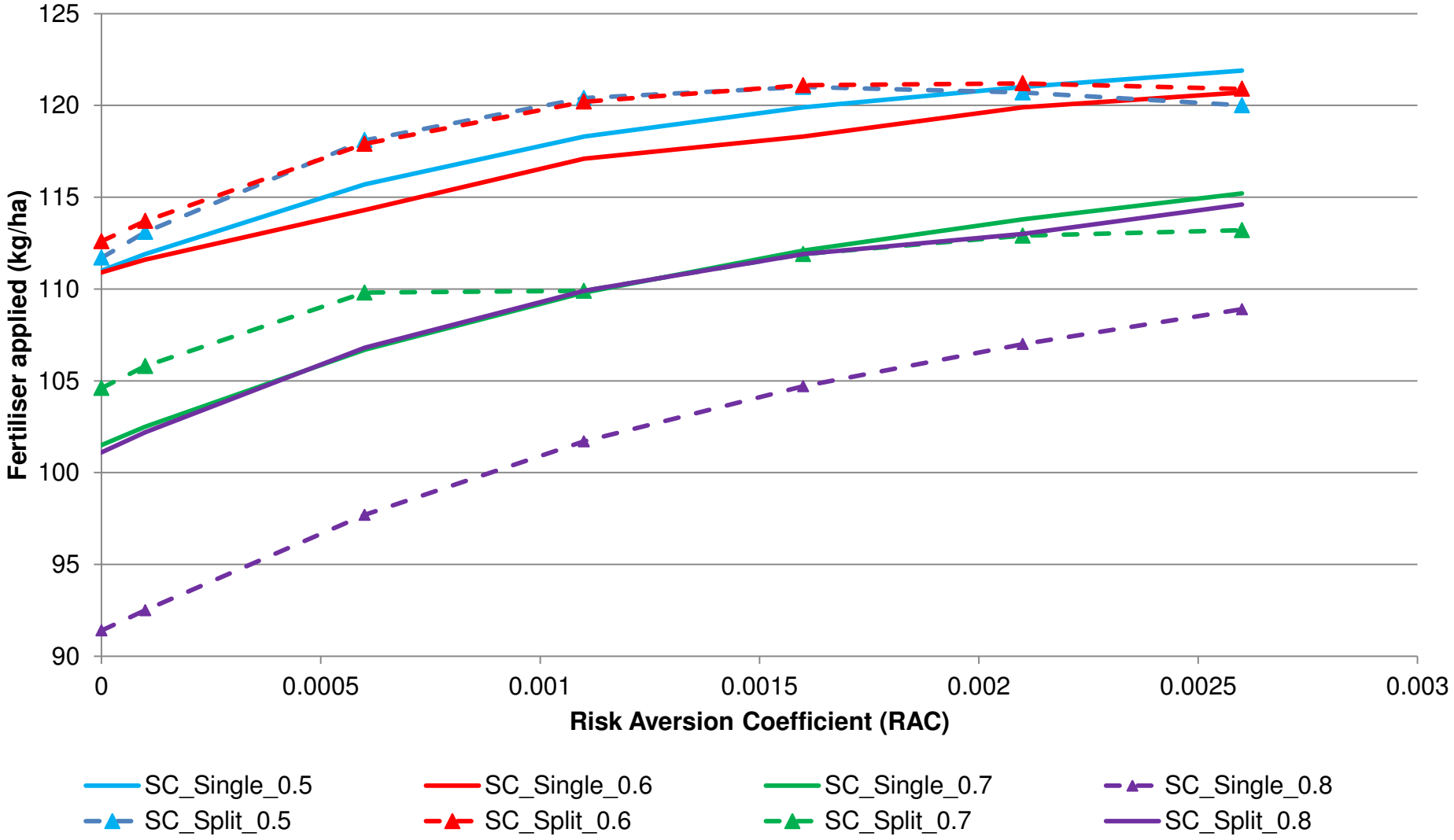
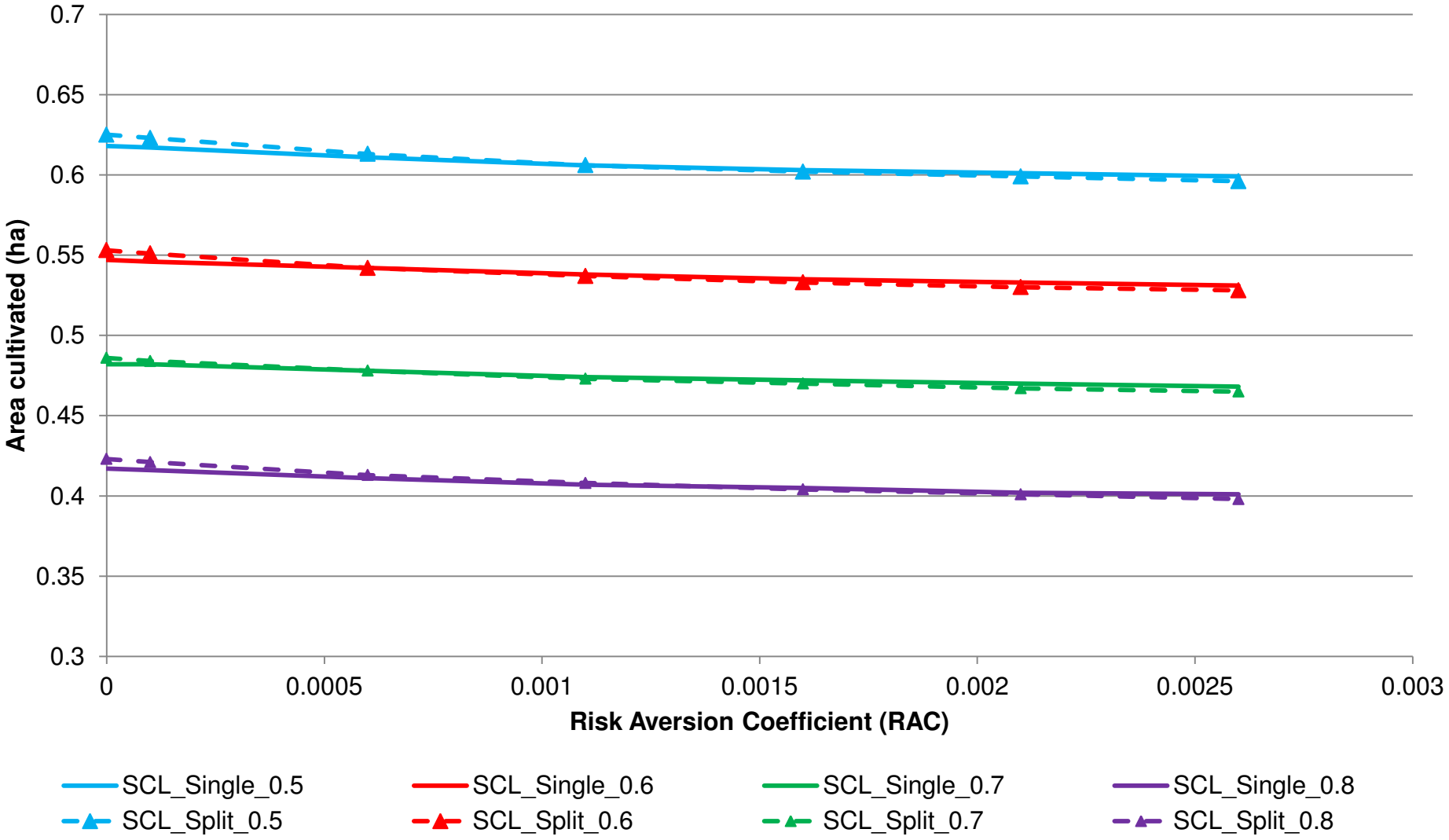


AREA CULTIVATED ON A SANDY CLAY LOAM SOIL FOR A SINGLE AND SPLIT APPLICATION FOR INCREASED RISK AVERSION (RAC) FOR COMPLIANCE TO AN ENVIRONMENTAL GOAL OF 28KG/HA FOR FOUR COMPLIANCE PROBABILITIES



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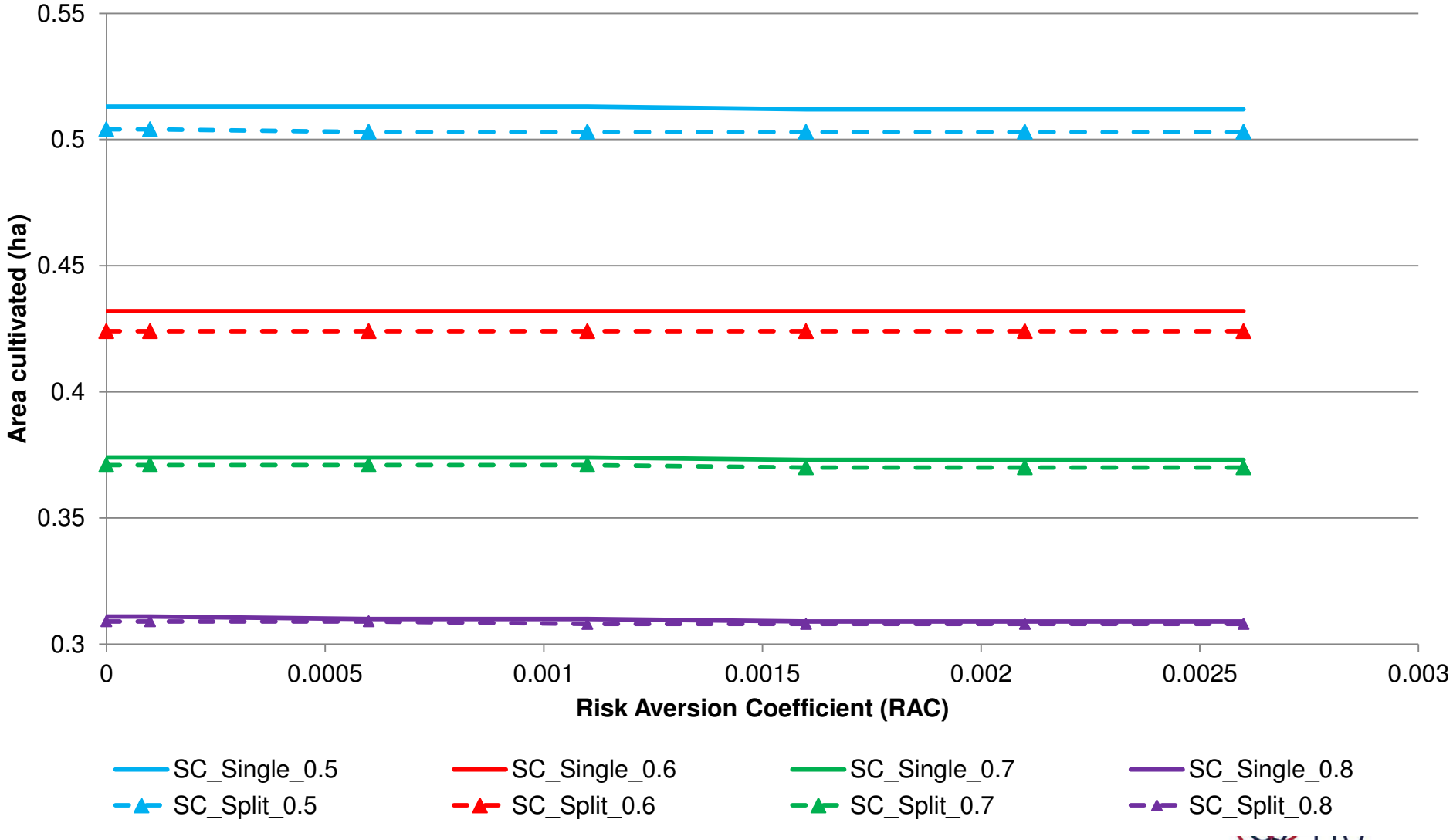

CONCLUSIONS

- The presence of an environmental constraint has a significant impact on the risk efficiency frontier.
  - The mismatch between production risk efficiency and environmental risk efficiency pose problems for environmental regulation.
- Decision maker's risk-behaviour affects the production decision made.
  - More risk averse decision makers tend to apply more fertiliser than a risk neutral decision maker.
  - It is important that during the development of the incentives and standards that will ensure the internalisation of the externality that the risk behaviour of decision makers is taken into account.

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- The presence of an environmental constraint impact production decisions significantly with substantial compliance costs
- The compliance cost results indicated that irrelevant of risk aversion, decision makers would prefer producing on a SCL soil.
  - The choice between a split and single application of fertiliser is not as straightforward as the compliance level, soil type and risk aversion influence the choice of application technique
- Soil specific recommendations are necessary

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FUTURE RESEARCH

- Due to the estimation of an endogenous target the upper partial moment might be conservative in its estimation of the economic-environmental trade-offs.
  - Future research should address the conservativeness of the upper partial moment and evaluate the effect of such conservativeness.
- Furthermore, the study did not account for timing of fertiliser application when applying fertiliser in a split application.
  - It was assumed during the data simulation process that fertiliser is applied using a fixed application schedule.

Thank You
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