British Council-MIUR/CRUI Partnership Programme

A multi-factorial analysis of the impact of climate change on marginal agriculture systems.

Summary of findings

UK partners: Keith B. Matthews, M. Rivington

Address: Macaulay Institute, Craigiebuckler, Aberdeen. AB15 8QH. U.K.
Tel: +44 1224 318611
Fax: +44 1224 311556
Email: k.matthews@macaulay.ac.uk
m.rivington@macaulay.ac.uk

Italian partner: Gianni Bellocci

Address: ISCI, via Corticella 133, 40128 Bologna, Italy
Tel: +39 501 631 6846
Fax: +39 501 37 4857
Email: g.bellocchi@isci.it

Background

The award allowed MI and ISCI to undertake six exchange visits over the course of 18 months. In the first two visits there were opportunities for the two research teams to undertake in-depth familiarisation with each other's research projects, present these projects to wider audiences at the two institutions and to agree the detail of the collaborative project. Subsequently, there were four exchange visits to undertake data gathering, simulation modelling and analysis.

Joint publications: to date 3 conference papers have been published:

1. Rivington, M., Matthews, K.B. and Buchan, K. (2003). *Quantifying the uncertainty in spatially explicit land-use model predictions arising from the use of substituted climate data*. MODSIM 2003, International Congress on Modelling and Simulation, Integrative Modelling of Biophysical, Social and Economic Systems for Resource Management Solutions, Townsville, Australia, 14-17 July 2003

2. Rivington M., Bellocchi G., Matthews K.B., Buchan K. (2004). *An Integrated Modelling Approach to Conduct Multi-Factorial Analyses on the Impacts of Climate Change on Whole-Farm Systems*. In Pahl, C., Schmidt, S. and Jakeman, T. (eds) iEMSs 2004 International Congress: "Complexity and Integrated Resources Management". International Environmental Modelling and Software Society, Osnabrueck, Germany, June 2004. Proceedings as CD-Rom. This paper has resulted in an invitation to submit an extended version to the journal Environmental Modelling and Software

3. Bellocchi G., Rivington M., Matthews K.B., Buchan K. and Donatelli M. (accepted). *Scenario Characterisation Within A Multi-Factorial Study Of Climate Change Impacts On Whole-Farm Systems.* Proceedings of the European Society for Agronomy, Copenhagen, July 2004

Principal findings of the joint research

Climate metrics

Long-term daily weather records observed at the two sites were used to generate 50 years of baseline and altered climate data sets, by using the ClimGen stochastic generator. Climate change data were produced by two Global Circulation Models (GCM): Canadian (C); and Hadley (H), representing projected conditions at 2030 and 2090. To characterise the climate change scenarios as an initial evaluation, a set of assessment metrics were developed. The metrics identify changed conditions significant to the agro-ecosystems.

The analysis showed that higher precipitation levels at Hartwood tend to worsen problems related to water excess (e.g. leaching and runoff), with the Hadley scenarios giving higher excess winter rainfall. Warmer temperatures are more favourable to cropping. Both C and H indicated earlier and more rapid crop establishment, with last spring air frost dates on average 13.5 days earlier, accumulated temperatures above 0 °C for January to June 21% higher and 2-3 additional months with mean air temperature above 5 °C.

All scenarios suggested that droughts would become more common for the Italian study-site due to a decrease (9-30%) in precipitation). The yearly rainfall distribution is also more heterogeneous and thus less predictable. The decrease combined with the elevated temperatures resulted in 14-51% greater periods of air-dried soil. Non-irrigated crops in Italy would experience more water stress while irrigation requirements would be increased.

In general, warmer and wetter conditions in Scotland may favour productivity; whilst in Italy water stress may impose limits. Access to land at Hartwood remains an issue, and there will be an increased irrigation requirement for Montepulciano.

Individual crops

Italian site. Crop growth and development were simulated over 50-year period by means of a generic crop simulator (CropSyst) to compute average productivity and length of growing seasons for both the baseline climate and altered climate scenarios. Simulations were run either resetting or not resetting initial soil conditions. The latter allowed carry-over effects from one year to the next to be assessed, when starting conditions for the following crops are altered.

For heat-loving crops, such as tomato and capsicum, climate changes increased productivity (~40%), but require much greater water supply to meet crop requirements. Productivity of winter-growing crops such as durum wheat did not change particularly (-16% with Canadian 2030; +11% with Canadian 2090): warmer temperatures made the growing season shorter (7-28 days less), helping the crop to avoid summer water shortages, but at the same time limiting the time available to the crops for accumulating biomass. Perennial crops such as alfalfa experienced an increase in consumptive demand for water; the size of the increase depending on the climate scenario. In general, higher water stresses were associated with a reduced number of clipping events for fodder (e.g. 1.85-2 cuts per year in average with Canadian 2030 against 2.3-2.4 with baseline climate) and, consequently, with a lower amount of forage available to livestock.

Scottish site. Spring barley and winter wheat are grown as 'whole-crops' for fodder, i.e. the whole plant is harvested, rather than just the grains. The crop simulations were set to conduct the harvest 10 days after the crop reaches maturity. Spring barley shows a substantial decrease in total above ground biomass (AGB) from 10.2 t/ha in the 'no CC' scenario to 8.5 t/ha in both H and C scenarios. This is primarily due to a reduction in the time it takes for the crop to reach physiological maturity, where the harvest date is approximately 24 days earlier for 2090. The crop therefore has less time to accumulate biomass. There is also a slight increase in variability between each years' AGB production (indicated by a larger standard deviation). Winter wheat (planted in the autumn) shows a similar response, with AGB falling from 18.5 t/ha to 10.5 t/ha from the 'no CC' to both Hadley and Canadian GCM 2090 scenarios. Harvest takes place considerably earlier (approx. 47 days) in the year, reflecting the faster rate at which the crops accumulate thermal time (due to higher temperatures) – the process that controls crop development. This changes the average harvest date from 2nd September to 17th July, raising the question as to what potential there may be for a catch crop or earlier grass sowing.

Cropping systems

Italian site. Four rotations, representative of the most typical crop patterns for the site under study, were run and evaluated. Two of the rotations had 4-year alfalfa as a fodder crop and either tomato or capsicum as the horticultural crop, vis.: *sugar beet - durum wheat - horticultural crop - alfalfa (4 years) - durum wheat - tobacco Kentucky*. The alfalfa was replaced by spring-sown grain crops and set aside (non-food sunflower) in the third rotation: *sugar beet - durum wheat - tobacco Kentucky – maize – sunflower - durum wheat - set aside*. This rotation, in which maize was is preceded by triticale as a forage catch-crop, is the most complex crop pattern. The fourth rotation was based on the growing of tobacco Virginia Bright: *sugar beet - durum wheat - tobacco Virginia Bright (3 years) - durum wheat*. This is the simplest rotation.

These rotations were run over different soil-climate scenario combinations (7 soils by 5 (1 base + 4) climates). Rotational yields were calculated averaging yields of each crop over the 50-year run. Large effects on dry matter production were caused by either differences in soil (from sandy-loam to light-clay), climate or cropping history. Grain yield of winter wheat was about 40% lower in the most complex rotation than in other rotations. Other crops did not show differences in yield from being introduced into different rotations. Winter wheat was observed to grow better over light-clay soils (average yield of about 6-7 t ha^{-1}), whilst some restrictions to yield are expected from silty-loam soils (about 3-4 t ha^{-1}). Silty-loam soils were beneficial for tobacco Kentucky (about 2.5 t ha^{-1} of dry leaf biomass in average), sandy-loam soils being less suitable to Kentucky cultivation (about 1.7 t ha^{-1}). Climate effects tended to be similar to those observed with individual crop simulations.

Scottish site: Cropping systems at Hartwood farm in Scotland consist of grass silage production and/or mixed silage, grazing and whole cereal crops (spring barley and winter wheat harvested before maturity for livestock fodder). In the silage system there is a single cut, usually in late June, and grazing may take place afterwards. Simulation results for the silage system indicate that there would be a 12% increase in silage yield for the 2030 scenarios and a 21% increase for 2090. This increase in the yield total is associated with a more rapid grass growth in spring and early summer, raising the potential for an additional cut to be made later in the summer.

These simulations, however, do not take into consideration the grass silage quality, an important factor relating to livestock productivity. Quality is related to plant phenology; the relationship between thermal time accumulation and plant development (as opposed to growth). The higher temperatures associated with climate change scenarios means that crops develop quicker, i.e. move from one physiological stage to another in a shorter time, but without necessarily having a proportional increase in accumulated biomass.

As with the results from simulations of individual crops above, the results for productivity in *grass - spring barley – winter wheat – grass* rotations show a decreasing cereal whole crop yield. Spring barely as part of a rotation in the base scenario gave a mean whole crop yield of 9.9 t ha^{-1}, which decreased to 7.4 t ha^{-1} by 2090. Winter wheat whole crop yields fell by over 50%, in a similar fashion to the results for the individual crops results above. Again this can be attributed to the crop reaching maturity much earlier, and hence reducing the amount of time for biomass accumulation. These results suggest that spring barley and winter wheat may not be viable fodder crops in future climates.

Farming systems

To date, due to other commitments it has not been possible to complete the analysis of the integrated cropping/livestock systems. The environmental databases for the two sites have been created and the land management infrastructure defined within the geographical information system. Further analysis of the Italian soil survey data is being undertaken to refine the environmental database, particularly for the prediction of hydrological impacts. Typical patterns of land use derived from the systems of rotation have been implemented. The MI livestock system model has been parameterised for the Montepulciano stockyard system and preliminary testing conducted. The implications for the livestock systems of the changes to individual crops and crop rotations are to be undertaken in summer/autumn 2004. The information required for the labour and machinery profiling has been secured from Italian sources and is being used to define management regimen. This in turn will be combined with the financial information gathered to complete the final financial impact assessment.