SCENARIO CHARACTERISATION WITHIN A MULTI-FACTORIAL STUDY OF CLIMATE CHANGE IMPACTS ON WHOLE-FARM SYSTEMS

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Holistic studies of climate change (CC) impacts on whole farm systems require a range of assessment metrics to characterise the change scenarios. Characterisation of the change scenarios is required to enable results from an overall holistic study to be put into context, aiding interpretation of output, which will then permit potential adaptation and amelioration strategies to be identified and developed. This study details the use of several metrics, as the first part of a comprehensive holistic study to investigate and quantify the additional risk that climate change may have on the financial, social and environmental viability of two different farming systems.

Materials and methods

Sites and weather Climate change data were produced by two Global Circulation Models (GCM): Canadian (C); and Hadley (H), representing projected conditions at 2030 and 2090 for farms in two locations. One is an upland farm in Scotland, UK (Hartwood), characterised by cold wet winters and cool moist summers, with a combined sheep and suckler cow grazing system. The other is in Tuscany, Italy (Montepulciano), with cool moist winters and warm dry summers, with an integrated cropping and indoor reared beef system. Climate metrics Current and changed climates, applied to both sites over a 50-year period, were characterised by a set of assessment metrics chosen in order to capture projected changes in those conditions regarded to be of importance to soil accessibility and land use productivity. Summary statistics (mean, median) and exceedence probabilities (Pe) were applied to basic weather variables such as rainfall (R), air temperature (T) and evapotranspiration (ET_0). Additional metrics were derived from the basic data (AP: access period (days); SMD_m: maximum summer soil moisture deficit (mm); ADS: air-dried soil (days); RFC: return to field capacity (date); EFC: ending field capacity (date); EWR: excess winter rainfall (mm); Fm: modified Fournier index (mm); $AT_{>0(Jan-Jun)}$: accumulated temperatures above 0 °C for January to June (°C-d); LSAF: last spring air frost (date); $M_{>5}$: mean air temperature above 5 °C (months)). Holistic whole-farm study. LADSS, a multiple-objective strategic land-use planning tool (Matthews et al., 1999, 2003, http://www.mluri.sari.ac.uk/LADSS/ladss.shtml), which incorporates the CropSyst model (Stöckle et al., 2003), was employed for conducting a wide range of counter-factual analyses assessing the changes to the land management, based on site-specific biophysical conditions.

Results and discussion

Basic and derived weather metrics are reported in Tables 1 and 2 respectively. Fig. 1 shows exceedence probabilities for Fm. The C scenario showed declines in precipitation in Italy compared with present climate; it also showed greater temperature increases than the H scenario. Temperature increases were comparable between the two GCM, while H provided a larger precipitation increase than C. *Hartwood* Higher precipitation levels at Hartwood tend to worsen problems related to water excess (e.g. run-off, soil erosion), with H scenarios giving higher EWR. For both C and H, there is little difference in dates for EFC, and AP. Warmer temperatures in general appear favourable to land use production. Both C and H indicate potential earlier, more rapid crop establishment with LSAF dates being on average 13.5 days earlier, $AT_{>0}$ 21% higher and $M_{>5}$ increasing by 2-3 months. The SMD_m changes indicate that crops may experience some water stress according to the C scenarios. Fm probabilities depict a tendency towards increasing heterogeneity in yearly rainfall distribution with CC. *Montepulciano* CC projections all suggest that droughts will be more common in the future for the Italian study-site (9-30% decrease in precipitation), thus posing the problem of creating new water storage to support a productive agricultural activity. Warm winters reduce the risk of spring frosts, and long dry summers increase problems associated to soil water deficit (days with ADS increasing of 14-51%). Temperature changes are potentially good for crops, even if they require more water supply to meet their growth requirements (especially for summer-growing crops). Dryer soils from CC, in which the production of a fine tilth can be difficult, pose problems of suitable conditions for tillage. Fm probabilities indicate some kind of homogeneity in the yearly rainfall distribution under C scenarios.

Tab. 1 – Average values for long-term generated R, T and ET_0 at two sites under alternative climate scenarios.

Climate scenarios	Hartwood			Montepulciano		
	R (mm yr^{-1})	T (°C)	ET_0 (mm yr^{-1})	R (mm yr^{-1})	T (°C)	ET_0 (mm yr^{-1})
current	1178	7.7	466	770	13.9	1046
C2030	1110	8.9	486	542	15.1	1122
C2090	1270	10.4	503	562	16.8	1186
H2030	1256	8.9	482	703	14.7	1088
H2090	1279	10.1	500	732	16.4	1165

Tab. 2 – Median values for metrics from long-term generated R, T and ET_0 at two sites under alternative climate scenarios.

Assessment metrics	Hartwood					Montepulciano†				
	current	C2030	C2090	H2030	H2090	current	C2030	C2090	H2030	H2090
AP (days)	185	188	193	185	188	318	346	365	332	326
EFC (date)	84	86	84	84	81	28	1	1	14	15
RFC (date)	272	277	277	273	273	330	343	346	334	329
SMD_m (mm) | ADS (days)	85	48	60	82	76	73	105	110	83	86
EWR (mm)	564	537	581	600	628	77	0	0	35	45
LSAF (date)	130	119	116	119	112	30	0	0	3	0
$AT_{>0(Jan-Jun)}$ (°C-d)	1149	1197	1503	1350	1519	2143	2318	2632	2289	2576
$M_{>5}$ (months)	8	8	11	10	11	11	12	12	12	12

† There may not be a return to field capacity in dry years. Median values for RFC refer to years when RFC was attained.

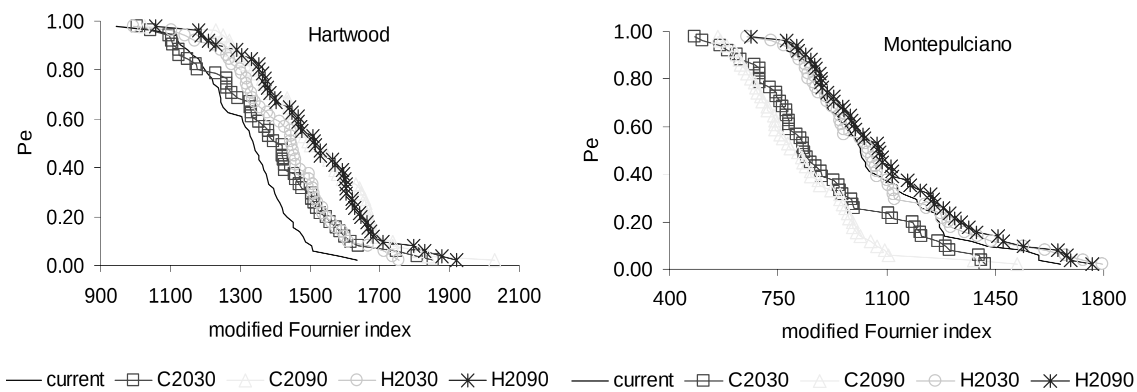

Fig. 1 - Probability of exceedence for the modified Fournier index (Fm) at two sites under alternative climate scenarios. Large values indicate heterogeneity in yearly rainfall.

Conclusions

The results demonstrate the need to characterise climate change scenarios as part of holistic whole farm impact studies. Warmer, wetter conditions in Scotland may favour land use production, whilst in Italy water stress may limit some land uses. Access to land at Hartwood appears not to be an issue, but there will be an increased irrigation requirement for Montepulciano. These results can be referenced with LADSS output to identify the subtleties of CC impacts, i.e. how CC impacts manifest themselves and relate to changes in land use management and subsequent financial, social and environmental impacts.

References

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