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Characterization of north-eastern Australian environments using APSIM for increasing rainfed maize production

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ABSTRACT

Recurring water stresses are a major risk factor for rainfed maize cropping across the highly diverse agro-ecological environments of Queensland (Qld) and northern New South Wales (NNSW). Enhanced understanding of such agro-ecological diversity is necessary to more consistently sample target production environments for testing and targeting release of improved germplasm, and to improve the efficiency of the maize pre-breeding and breeding programs of Qld and New South Wales. Here, we used the Agricultural Production Systems Simulator (APSIM) – a well validated maize crop model to characterize the key distinctive water stress patterns and risk to production across the main maize growing regions of Qld and NNSW located between 15.8° and 31.5°S, and 144.5° and 151.8°E. APSIM was configured to simulate daily water supply demand ratios (SDRs) around anthesis as an indicator of the degree of water stress, and the final grain yield. Simulations were performed using daily climatic records during the period between 1890 and 2010 for 32 sites-soils in the target production regions. The runs were made assuming adequate nitrogen supply for mid-season maize hybrid Pioneer 3153. Hierarchical complete linkage analyses of the simulated yield resulted in five major clusters showing distinct probability distribution of the expected yields and geographic patterns. The drought stress patterns and their frequencies using SDRs were quantified using multivariate statistical methods. The identified stress patterns included no stress, mid-season (flowering) stress, and three terminal stresses differing in terms of severity. The combined frequency of flowering and terminal stresses was highest (82.9%), mainly in sites-soils combinations in the west of Qld and NNSW. Yield variability across the different sites-soils was significantly related to the variability in frequencies of water stresses. Frequencies of water stresses within each yield cluster tended to be similar, but different across clusters. Sites-soils falling within each yield cluster therefore could be treated as distinct maize production environments for testing and targeting newly developed maize cultivars and hybrids for adaptation to water stress patterns most common to those environments.

1. Introduction

Maize (*Zea mays* L.) is one of the preferred feedstock in the intensive livestock industries in Australia (Hammer et al., 2003). The demand for maize in Australia is >400 kt/year whereas production is about 360 kt/year. An appreciable amount of the maize demand is currently met by rainfed (52%) and irrigated (40%) production systems in Victoria, Queensland, and New South Wales, which account for 2%, 54% and 43%, respectively, of the total maize area of maize in Australia (Fig. 1). The importance of the crop has recently increased because of its use as human and pet food, and potential for ethanol production (Rendell, 2006; Higgins, 2006), besides the export demand for non-genetically modified maize grain to Asia. Hammer et al. (2003) already argued that a substantial increase in area the of all feed crops, including maize, will be required to meet the growing grain demand from the feedlot industries in north eastern Australia. However, in view of the continuous increase in the cost of cultivation and the availability of less risky alternative crops (e.g. sorghum), the only way forward to meet the growing demand for maize will be to significantly increase production, productivity and yield stability.

High maize yields of up to 21 t/ha have been recorded in the fully irrigated commercial plantings in Victoria, Australia (Birch et al., 2006). In Queensland and northern New South Wales (NNSW), which grow about nearly 90% of maize under rainfed conditions, the average yield is <5 t/ha (ABARE, 2006). Sustainable intensification of maize in this region will therefore require breeding high and

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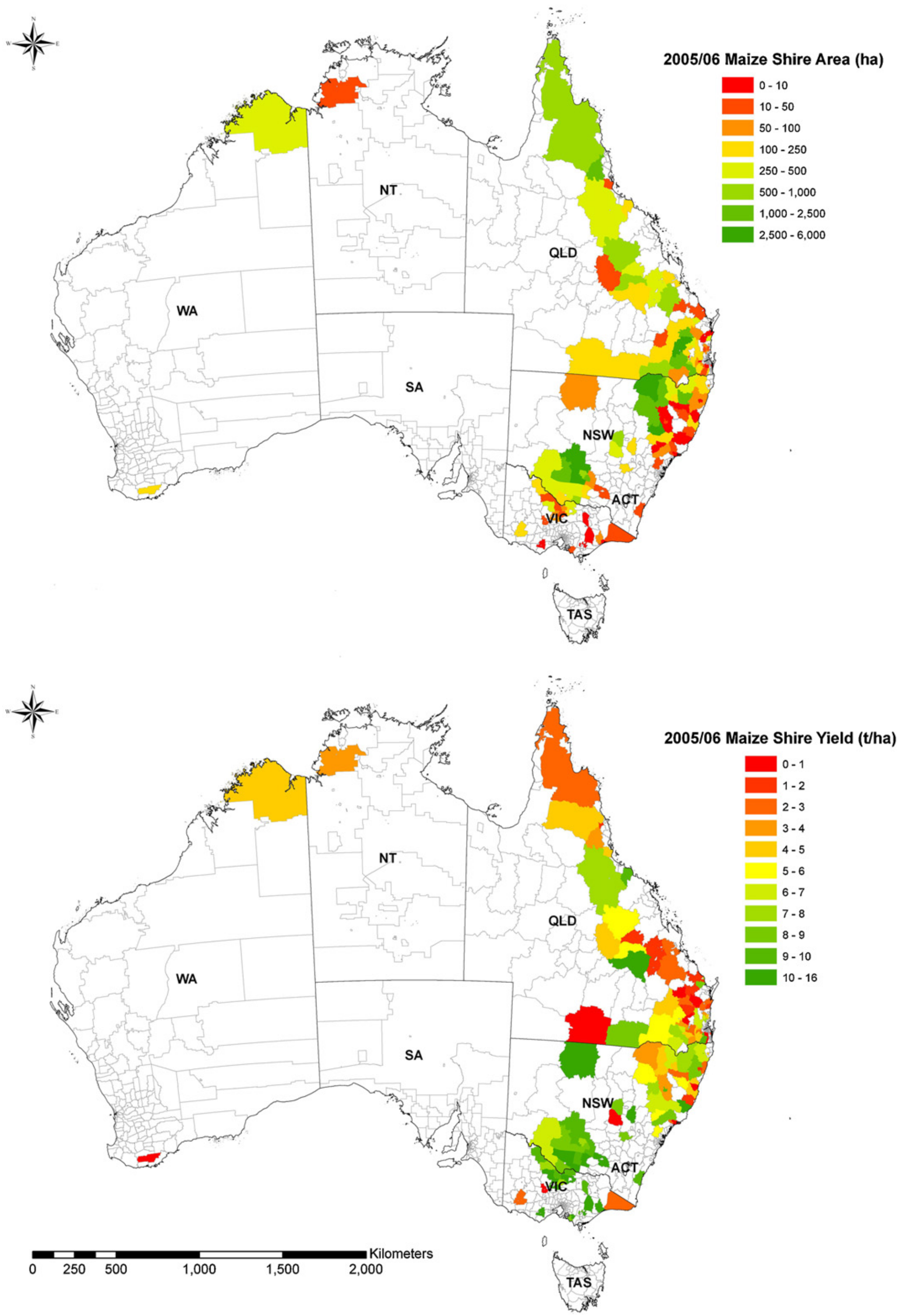

Fig. 1. Area and yield of maize in Australia in 2005–2006.

Source: ABARE (2006).

stable yielding germplasm, besides improved agronomic management, to enable better adaptation to the rainfed growing conditions across northern Australia (Birch et al., 2008).

Rainfed crops grown in this region are subjected to a range of water stress patterns, resulting in complex interactions between the genotypes (G), environments (E) and management (M) (Chapman et al., 2000a,b; Chenu et al., 2011). Such interactions also impose challenges to maize breeders. Therefore, precise characterization of these stress patterns and better understanding of $G \times E \times M$ is important to positively exploit these interactions in breeding strategies (Chapman et al., 2000a,b; Chenu et al., 2011, 2013).

Plant breeders often compare the performance of a range of elite genotypes relative to the checks in different environments