Is Australia's wheat productivity under threat

A.P. Hamblin and G.W. Kyneur.

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Summary. Trends in wheat yield in 206 Shires (and Counties) of the Australian wheat belt were analysed for 1950-91 against cropping practices, rainfall and evidence of soil change. Highest trends occurred in central Queensland and in southern NSW but over a third of all Shires had low or negative yield increase. There was strong indirect evidence that low trend values could be attributed mainly to declining soil fertility and nitrogen supply. There were no consistent and significant trends in rainfall related to yield trend for the full period. Regions which showed a significant positive yield trend in the past decade showed evidence of greater use of grain legumes. nitrogen fertilisers and legume-pastures in rotations.

Introduction

Soil organic matter and nitrogen supply in Australian field-crop soils are not monitored regularly on a national basis. Wheat yield trend may however, provide a surrogate indicator of changes in soil condition. There are many experimental studies which suggest continuous cropping, and a lack of legumes in rotations deplete soil fertility (3,4). Our objective was to compare yield trend values between Shires, over the past 42 years. in association with trends in such factors as rainfall, areas of crops, sown pastures and grain legumes, quality and duration of pastures, and volumes of fertiliser nitrogen, using regularly collected statistics.

Methods

Local Government Area or Shire (County in South Australia) was used as the scale of analysis. The data were compiled from the Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural and Resource Economics (ABARE) (1.2). Rainfall data were supplied by the Bureau of Meteorology. Recording stations located in wheat growing areas of the Shires and Counties were mapped by the National Resource Information Centre (NRIC) of the Bureau of Resource Sciences (BRS). Details are given in (6).

The coefficient of the linear regression of yield on year (1949-50 to 1990-91) provided the trend values. Quartic regression curves were also fitted to the data to identify direction of trend, particularly in the final decade (1981-91). The correlation between rainfall and yield trend was examined at State and regional level using the annual and growing season rainfall of relevant Shires. Regions were aligned to rainfall or wheat maturity zones. Grain yield per mm rain was used to compare districts where farming practices differed, but where no direct soil chemical evidence was available to assess soil fertility.

Agricultural census statistics at the Shire level cannot provide information on effects of cropping on soil fertility, as the number of crops (cultivations) in a rotation per paddock *(cropping intensity)* is not reported. Instead, the total area of pasture and crop per Shire is aggregated from individual farms. This ratio, crops to pastures per Shire, is described as the *cropping percentage.* Thus in parts of the country where pastures are not rotated with crops, as in much of Queensland, the cropping percentage does not necessarily reflect the cropping intensity. In that State ABS data now include the area ploughed up from pasture. which demonstrates a high cropping intensity even in Shires with an apparent low cropping percentage. For the last five years of the period a supplementary survey of ABARE's annual Farm Survey allowed the cropping intensity to be calculated for the whole country (1).

Results and discussion

In southern Australia. wheat culture has relied on annual clover or medic leys for livestock and as the major source of soil nitrogen. Effects of this practice on soil organic matter and yield of subsequent wheat crops have been well documented. The two fundamental requirements are the optimisation of production of legume biomass and nitrogen fixation during a pasture phase, and a maximum cropping intensity of 50-60% (8). From Table I it can be seen that highest trends occurred in central Queensland and southern New South Wales, and lowest in medium and low rainfall zones of SA. The direction of yield trend in the 1980s was still zero or negative in some 22% of Shires analysed.

Table 1. Australia: Wheat yield trends and cropping frequency by State and region
Source:[a] ABARE survey (1991). Cropping intensity is the frequency of cropping per paddock

State	Region	Cropping intensity[a] 1983-89 (%)	Direction of trend 1980-91 (No.Shires)			42-year yield trend (kg/ha/y)	42-year average cropping (%
			+	0	-ve		
Queensland	Central	97	5	1	0	25 ± 2	24
	South West	90	3	5	1	10 ± 4	48
	Darling Downs	98	8	3	0	19 ± 6	88
	State		*16*	*9*	*1*	*7 ± 5*	
New South Wales	North	90	18	0	1	15 ± 4	82
	Central	50	12	0	0	17 ± 5	63
	South	60	24	2	2	23 ± 7	43
	State		*54*	*2*	*3*	*17 ± 5*	
Victoria	Mallee	80	6	1	0	15 ± 4	52
	Wimmera	90	7	2	3	11 ± 6	42
	N and NE	50	14	2	6	9 ± 4	25
	State		*27*	*5*	*9*	*12 ± 5*	
South Australia	A(<350mm)	85	2	0	7	4 ± 3	74
	B(351-400mm)	70	5	0	2	5 ± 1	70
	C(401-500mm)	60	7	1	1	11 ± 4	64
	State		*14*	*1*	*10*	*3 ± 4*	
Western Australia	A(<325mm)	75	17	0	0	6 ± 4	71
	B(326-450mm)	60	27	0	3	15 ± 6	48
	C(451-500mm)	50	5	0	3	18 ± 1	34
	State		*49*	*0*	*6*	*10 ± 3*	

Annual and seasonal rainfall and yield trends were very poorly correlated at higher orders of spatial aggregation (State level), with linear and curvilinear correlations of $r^2 = < 0.30$. Many individual Shires showed a curvilinear (quadratic) response between annual yield and annual rainfall; the highest yields occurred with rainfalls intermediate in the range recorded. The wettest rainfall zones in Victoria and Western Australia showed negative relationships with rainfall: in the Wimmera this was significant (r^2=0.54, P<0.01). The strongest positive correlations were found in central and southern New South Wales (r^2=0.40) and in the 326-450 mm rainfall belt of Western Australia. While long-term rainfall trends did not vary significantly over the forty year period, shorter-term fluctuations in rainfall were positively associated with increased yield trend for parts of Western Australia in the 1980s.

The high yield trend in Central Queensland is attributed to the innate fertility of soils cleared of leguminous Brigalow scrub in the 1950s. In Queensland's south west, soils of lower initial fertility have been continuously cropped, and yields are static. Although the area of sown pastures in Queensland doubled between 1950 and 1990. cropping intensities are still high (80-90%) and negligible use is made of pastures as leys. Recent decline in yield trends in some initially fertile soils of Shires in the Darling Downs is of concern.

In southern NSW high yield trends are associated with clover leys in crop rotations. The highest trend in the region (39 kg/ha/y) was shown by Cootamundra Shire (lat. 34.6S) where cropping percentage has not exceeded 40% for the full period, with 2-3 year leguminous pasture leys rotated with crops and input of fertiliser nitrogen increased from 5 to 26 kg/ha between 1981 and 1989, (1.2). The lowest trend in NSW (2 kg/ha/y) occurred in Walgett Shire (north west Zone, lat. 30.0S) where continuous cultivation has resulted in losses of up to 50% of soil organic matter, pasture leys arc not used and inputs of fertiliser nitrogen have been negligible (3). A crude rainfall-efficiency calculated as the grain yield per mm growing-season rain was used to assess soil fertility conditions between Shires with similar rainfalls. For example. in Central NSW the Shires of Cowra (Iat.33.8S) and Gilgandra (lat. 3I.6S), each with approximately 300mm of May-October rain, had trends of 29 and 12 kg/ha/y respectively. The cropping percentage in Gilgandra remained at 80-90% over the 42 years while in Cowra, where ley pastures have been rotated with crops, it did not exceed 50%. In Cowra rain-efficiency was 6 kg/mm but only 4 kg/mm in Gilgandra. Lower rain-efficiency of Gilgandra Shire suggests that high frequency of cropping (confirmed by ABARE's 1989 survey) has depleted soil fertility with consequent effect on yield trend. Further improvement in productivity would still be possible in Cowra Shire where grain legumes occupy only 5% of the crop area, input of fertiliser nitrogen was only 18 kg/ha in 1989, and most ley pastures were still non-leguminous (6).

In Victoria ABS census figures gave low *cropping percentages* in all Shires, but ABARE's survey indicates *cropping intensities* may be 60-80%, so many pastures may not be rotated with crops (6). As the average input of fertiliser nitrogen was only 5 kg/ha in 1989, and the proportion of grain legumes in crop rotations did not exceed 20%, nitrogen deficiency will be limiting wheat yields. In the North and North East, low wheat yields have previously been attributed to a combination of poor soil structure and nitrogen deficiency.

In South Australia rain-efficiencies were low, with 84% of Counties having values of less than 5 kg/mm. All areas had high cropping percentages (70-90%) until 1960, and remained above 60% in <400 mm annual rainfall districts (6). Duration of pasture leys averages only 1-2 years in South Australia, compared with 2-3 years in Western Australia, while even in the wetter regions only 50% pastures contain legumes (1). The low yield trend and rain-efficiency of zone C (Table I) are ascribed to soil factors, particularly nitrogen supply. This is supported by the data on high cropping intensities and short rotations, common in zones B and C (1). At the end of the 1980s fertiliser N still averaged only 10 kg/ha and only 12% of the crop area was under grain legumes in all zones (6). Light County, with the highest trend (17 kg/ha/year) and a mean yield of 1.5 t/ha over the same period, would require an extra 122 kg N/ha to raise the yield to 2 t/ha, but organic matter levels are generally too low for this.

In Western Australia the low trend value of zone A (<325mm) was associated with high cropping ratios (70-100%) throughout the period 1950-1991, with 10% grain legumes in crop rotations, and an average 12 kg N/ha during the 1980s (6). By contrast in the wetter zones (B and C), cropping percentages declined from >70% in the 1950-60s to 30-60% by 1970 and have remained at these values. In these zones higher rates of applied nitrogen (20 kg/ha) were used in the 1980s and, in some Shires of zone C, grain legumes (lupins) had attained a level of 30-35% of the crop area, with demonstrable effect on N nutrition (7). However, yield trends in zone (C) were no greater than in zone B. As in south-eastern Australia, a complex syndrome of disease, low N efficiency and weed problems are associated with higher rainfall regions which reduce yields from their expected potential (9).

The low rate of yield increase in many Shires has given Australia an average of only 8 kg/ha/y for the period, amongst the lowest of wheat producing countries with comparable conditions, starting from similar initial yield levels, such as South Africa and Morocco (21 kg/ha/y), Pakistan (34 kg/ha/y), Turkey (38 kg/ha/y) and India (43 kg/ha/y) (5). This has been in spite of the large expenditure on research and development to improve productivity, and the adoption of many technological changes by farmers to reduce costs. We conclude that, as there are some 113 of the 206 Shires and Counties where the *cropping intensities* exceeded 70% into the 1980s, with persistently low levels of grain legumes and N fertiliser application, soil nitrogen reserves have declined steadily and are associated with poor longterm crop performance. Unless rapid adoption of well-known technology occurs in areas of low productivity gain the profitability of wheat growing may be seriously in question in much of the "wheat belt" of Australia.

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