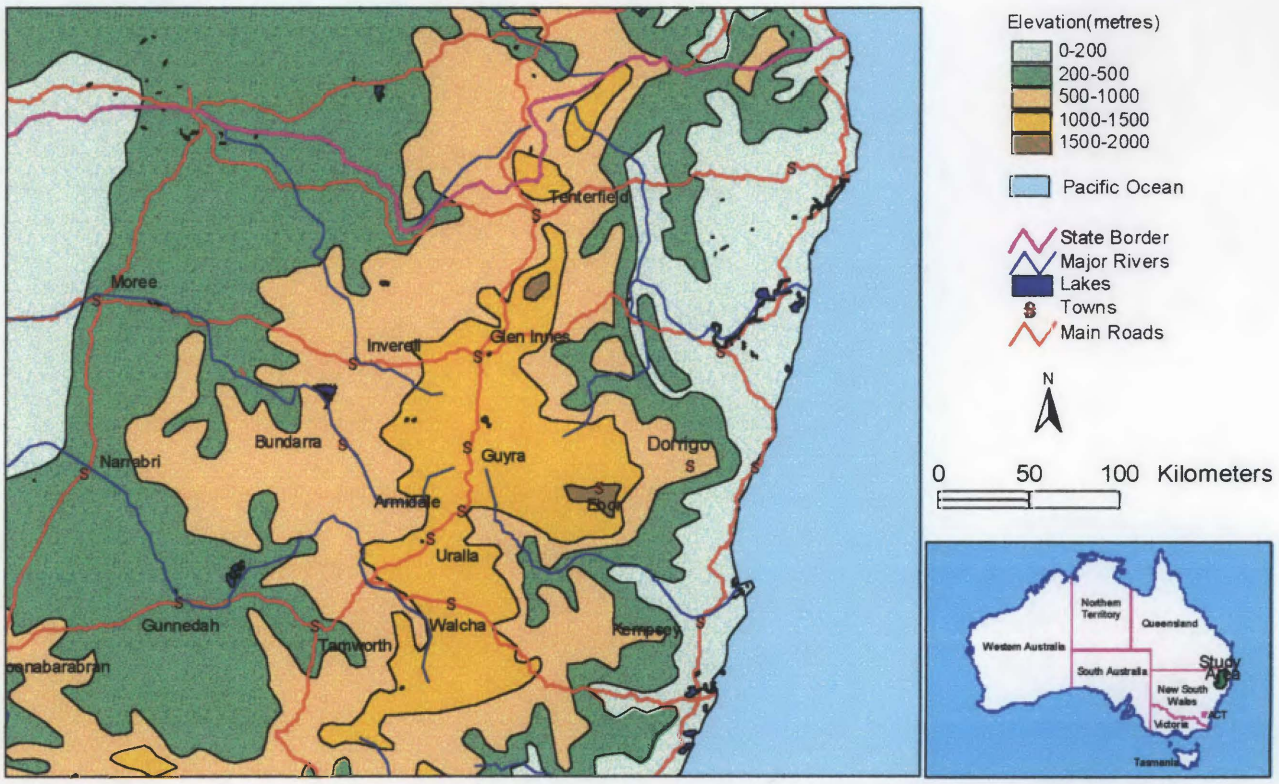
CHAPTER 3

SUITABILITY OF THE NEW ENGLAND TABLELANDS ENVIRONMENT FOR BUCKWHEAT PRODUCTION

3.1. INTRODUCTION

The Northern Tablelands (New South Wales) is roughly defined as the area which lies higher than 750-800 metres above sea level rising to some isolated peaks above 1400 metres. The boundary of the area extends from south of Walcha to the Queensland border. To the east is the escarpment with waters flowing into the coastal river systems. The western boundary runs east of Tamworth, Bundarra, and Inverell with water draining into the Namoi, Gwydir and Macintyre river systems.

The estimated area is 33 million square kilometres. The area under agricultural production is 2.2 million hectares, out of which only a small proportion (less than 1%) is cropped. The cultivated land is used for the crops such as maize, oats, soybeans and some vegetable production.



Map 3.1. New England Tablelands of New South Wales, Australia where the research was conducted.

3.2. CLIMATE

Buckwheat (*Fagopyrum esculentum* Moench) is very sensitive to high summer temperatures particularly during flowering and seed formation (Hennessy, 1992; Myers and Meinke, 1994). High temperatures and hot, dry winds, especially when moisture is scarce during flowering, can cause flower blasting and reduce seed set and yield of buckwheat (Campbell and Gubbels, 1979; Tahir and Farooq, 1988; Schmidt, 1995; Park, 1998).

Flowering in temperatures above 30°C is accompanied by desiccation of fruit and lowering of yield (Krotov, 1963). According to Bjorkman (1998), although the flowering lasts for several weeks, virtually the entire crop is normally set during the first 10 days of flowering (6 weeks after sowing). During this critical flowering period flowers are sensitive to temperatures over 32°C.

3.2.1. Mean daily maximum temperature (°C)

The mean daily temperature maxima for the buckwheat growing season (December to March) as recorded for the major areas (Guyra, Inverell, Armidale, Walcha, Bundarra, Uralla, Glen Innes and Tenterfield) of New England Tablelands are shown in Table 3.1 (Bureau of meteorology, Australia, 1999). The distribution of mean daily maximum isotherms in January for the various places of New England is shown in Figure 3.1 (Lea *et al.*, 1977).

The lowest mean daily maximum temperature for the buckwheat season was recorded as 21.8°C at Guyra during March and the highest mean daily maximum temperature was 30.3°C during January at Bundarra (Table 3.1).

Table 3.1. Mean daily maximum temperature (°C) during buckwheat growing period.

LOCATION	DEC	JAN	FEB	MAR
GUYRA	24.0	24.6	23.4	21.8
INVERELL	28.4	29.0	28.6	26.9
ARMIDALE	26.6	27.2	26.1	24.1
WALCHA	24.6	25.3	25.2	23.1
BUNDARRA	28.9	30.3	29.5	27.7
URALLA	26.0	26.5	25.5	23.9
GLEN INNES	24.4	25.0	24.4	22.8
TENTERFIELD	26.8	27.2	26.2	24.6

3.2.2. Mean number of days maximum temperature equal or exceeding 30°C

The long-term mean number of days maximum temperature equal or exceeding 30°C for various places of New England Tablelands are reported in Table 3.2 (Bureau of meteorology, Australia, 1999). These figures show that the temperature goes beyond 30°C at various places. The mean number of days above 30°C was higher at Bundarra followed by Inverell.

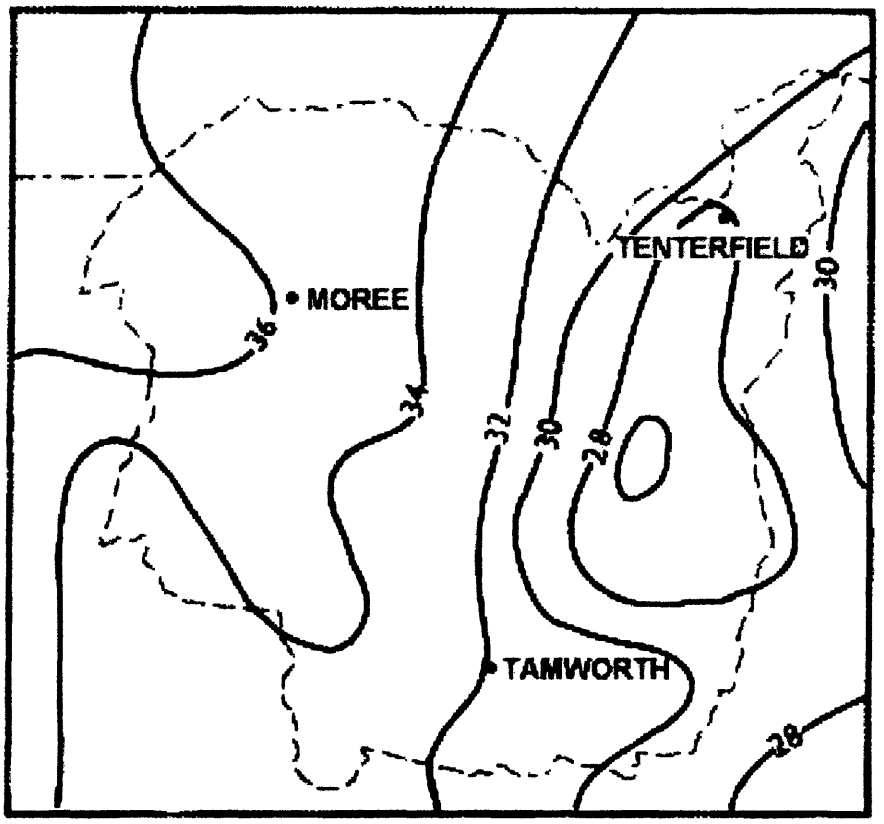


Figure 3.1. January mean daily maximum isotherms (°C) during buckwheat growing season (Lea, *et al.*, 1977).

3.2.3. Mean number of days maximum temperature equal or exceeding 35°C

The data presented in Table 3.3 (Bureau of meteorology, Australia, 1999) show that the long-term mean number of days maximum temperature equal or exceeding 35°C was higher (9.9) in December at Inverell than all the reported areas in the New England Tablelands.

Table 3.2. Mean number of days maximum temperature equal or exceeding 30°C during buckwheat growing period.

LOCATION	DEC	JAN	FEB	MAR
GUYRA	0	0	0	0.2
INVERELL	9.9	13.1	10.0	4.3
ARMIDALE	6.0	6.9	3.7	1.5
WALCHA	1.9	3.6	3.2	0.6
BUNDARRA	9.0	20.0	12.0	9.0
URALLA	0	0	0	0
GLEN INNES	3.0	4.8	2.7	1.0
TENTERFIELD	5.7	6.5	3.9	1.9

3.2.4. Daily minimum temperature (°C)

The mean daily minimum temperatures for the buckwheat growing season for various places in the New England Tablelands are presented in Table 3.4 (Bureau of meteorology, Australia, 1999). The lowest mean daily minimum temperature (9.2°C) as recorded in Guyra during March while the highest mean daily minimum temperature (16.4°C) as recorded during January in Inverell. The distribution of daily minimum isotherms for various places of the New England during January (summer) are shown in Figure 3.2 (Lea *et al.*, 1977).

Table 3.3. Mean number of days maximum temperature equal or exceeding 35°C during the buckwheat growing period.

LOCATION	DEC	JAN	FEB	MAR
GUYRA	0.0	0.0	0.0	0.0
INVERELL	0.9	0.7	0.6	0.0
ARMIDALE	0.3	0.2	0.1	0.0
WALCHA	0.1	0.2	0.0	0.0
BUNDARRA	0.0	0.0	2.0	0.0
URALLA	0.0	0.0	0.0	0.0
GLEN INNES	0.0	0.1	0.1	0.0
TENTERFIELD	0.3	0.4	0.2	0.0

Table 3.4. Mean daily minimum temperature (°C) during the buckwheat growing season.

LOCATION	DEC	JAN	FEB	MAR
GUYRA	9.8	10.8	10.8	9.2
INVERELL	15.2	16.4	16.3	14.5
ARMIDALE	12.2	13.4	13.2	11.2
WALCHA	10.6	11.8	12.2	9.7
BUNDARRA	13.4	14.6	14.5	12.3
URALLA	11.1	12.6	12.7	11.1
GLEN INNES	12.1	13.5	13.4	11.5
TENTERFIELD	13.0	14.4	14.3	12.5

3.2.5. Frost

3.2.5.1. Light frost (temperature < 2.0°C)

According to Bureau of Meteorology, Australia, (1999), the maximum mean number of days with a minimum temperature below 2°C was zero during buckwheat growing period for all the places in New England Tablelands except Walcha where one day in December and two days in March, frost can potentially occur.

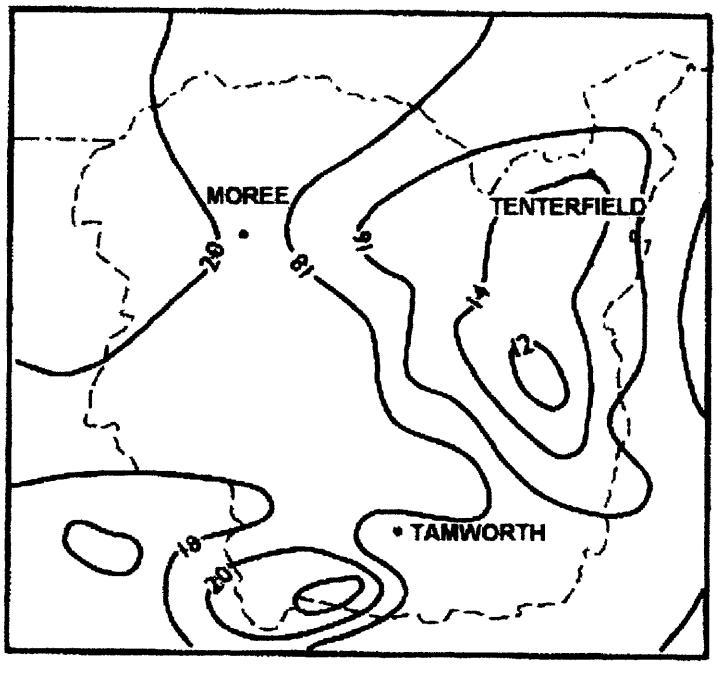


Figure 3.2. January mean daily minimum isotherms (°C) during buckwheat growing season (Lea *et al.*, 1977).

3.2.5.2. Heavy frost (temperature <0.0°C)

The mean number of days with minimum temperature less than 0°C (heavy frost conditions) for the buckwheat growing season during December to March in the major areas of New England Tablelands as recorded was nil except Walcha with 1 day likely during March (Bureau of meteorology, Australia, 1999).

It is evident from Table 3.1 that the long-term highest mean daily maximum temperature during buckwheat growing season (December-March) in the New England Tablelands was recorded as 30.3°C in Bundarra which is lower than the temperature level where flower blasting of buckwheat plant can take place. The mean number of days maximum temperature equal or exceeding 30°C was higher for Bundarra during the whole season of buckwheat followed by Inverell (Table 3.2). Moisture availability during this period to the plants is crucial otherwise higher temperatures combined with moisture stress would adversely affect the crop. The highest rainfall occurred during December and January (Table 3.5) which may supply moisture at this critical time of the growing period. However, the mean number of days (Table 3.3) indicate that there were some high number of days (9.9) at Inverell where the temperature was equal or exceeding 35°C during December. This range of temperature could potentially affect the flowers of buckwheat.

Minimum temperature is also very important for the growth of buckwheat. The lowest mean daily minimum temperature (Table 3.4) recorded for the New England Tablelands during the growing period of buckwheat did not drop below the optimum level where the growth of buckwheat can be seriously affected. The cool nights and high humidity are ideal for buckwheat growth (Schmidt, 1995; Park, 1998).

Based on the above information, it can be concluded that there is no threat to buckwheat crop due to higher and lower temperatures during its growing season (December to March) in the tabulated areas of the New England Tablelands except some part of the Inverell and Bundarra districts due to high number of days above or equal to 35°C temperature.

Buckwheat is extremely sensitive to both spring and fall frosts (Campbell and Gubbels, 1979; Robinson, 1980; Helm and Schneiter, 1986; Tahir and Farooq, 1988; Berglund, 1995; Grieve, 1995; Schmidt, 1995; Park, 1998). Based on the information on the frost data of the New England Tablelands, there is no threat to the buckwheat crop due to frost except at Walcha. There was only one day which has mean minimum temperature below 0°C (average of 10 years) during the buckwheat growing season in

March at Walcha. This may be a danger to the crop, however, due to its occurrence in the last month of the season, the crop may be harvested earlier in the risky month if sown early. In many of the protected areas in this locality a late frost may not be a threat. Buckwheat can be grown on all other areas of the New England Tablelands without the risk of frost.

3.2.6. Rainfall

The median rainfall for the buckwheat growing season for the major areas of New England Tablelands is presented in Table 3.5 (Bureau of meteorology, Australia, 1999). The highest median rainfall (105.4 mm) occurred at Guryra during January. The lowest median rainfall (49.3 mm) was recorded in Walcha during March. The total of maximum median rainfall during the buckwheat growing period occurred in Guyra (347 mm) while the total minimum median rainfall occurred in Bundarra (281 mm). The median rainfall and percentile for selected stations of the New England region during January is presented in Figure 3.3 (Lea *et al.*, 1977).

Table 3.5. Median (decile 5) rainfall (mm) during the buckwheat growing season.

LOCATION	DEC	JAN	FEB	MAR	TOTAL
GUYRA	94.8	105.4	84.9	61.6	347
INVERELL	82.6	87.4	75.6	52.1	298
ARMIDALE	80	91.6	72.3	53.9	298
WALCHA	80.6	95.2	71.1	49.3	296
BUNDARRA	78.2	86.8	63.8	52.1	281
URALLA	81.5	91.6	65.1	51.7	290
GLEN INNES	103.7	94.5	79.0	58.8	336
TENTERFIELD	97.6	101.4	76.2	62.5	338

Buckwheat has a small root system, so good soil moisture is needed throughout the growing season (Gubbels, 1978; Helm and Schneiter, 1986; Smith *et al.*, 1989; Myers and Meinke, 1994; Berglund, 1995).

Table 3.5 shows that on average, all the places of the New England Tablelands receive adequate rainfall during the growing season of buckwheat. Due to lack of information, the moisture requirements of buckwheat can not be quantified. However, the availability of moisture to buckwheat may not be a problem under the climatic regimes of the New England Tablelands.

3.2.7. Altitude

The New England Tablelands by definition is the area with altitude of 800 meters and above. Guyra has the highest altitude of 1200 to 1400 meters and some isolated peaks are above 1400 meters, but topographically are not suitable for cultivation. The relief of the New England Tablelands is shown by the Map 3.2 (Lea *et al.*, 1977).

The cultivation of buckwheat at higher altitudes is successful in many buckwheat producing countries, e.g. in Japan where it is cultivated at 1500 metres of altitude (Horiuchi *et al.,* 1995), Himalayas of Kashmir at 3000 to 3650 metres altitude (Parkash *et al.,* 1987; Narian, 1979). Growing buckwheat below an altitude of 800 metres greatly increases the risk of temperature and moisture stress largely because of the plant's relatively small rooting system (Hennessy, 1992). The New England Tablelands are appropriate for buckwheat production because of the area's higher altitude and comparatively lower summer temperatures.

3.2.8. Evaporation and moisture index

The average monthly evaporation (mm) in January (summer) for the New England is shown in Figure 3.4 (Lea *et al.*, 1977). It is indicated in this figure that monthly evaporation in most areas of the New England Tablelands is approximately 175 mm during the buckwheat growing season in the month of January, which is comparatively less than the other areas of New England except the areas near to the eastern scarp.

The moisture index presented in Figure 3.5 was derived from a mathematical model "G. I. = L. I. x T. I. x M. I." where G.I. (growth index), L. I. (light index), T. I. (thermal index) and M.I. (moisture index)] by Fitzpatrick and Nix (1970), relating plant growth to moisture availability in which rainfall, evaporation, and soil moisture were considered. This figure of the average seasonal moisture index in summer for the New England indicates that half of the region has an average seasonal moisture index of less than 0.4. However, it is up to 0.6 for the buckwheat growing areas on the New England Tablelands which seems to be favourable.

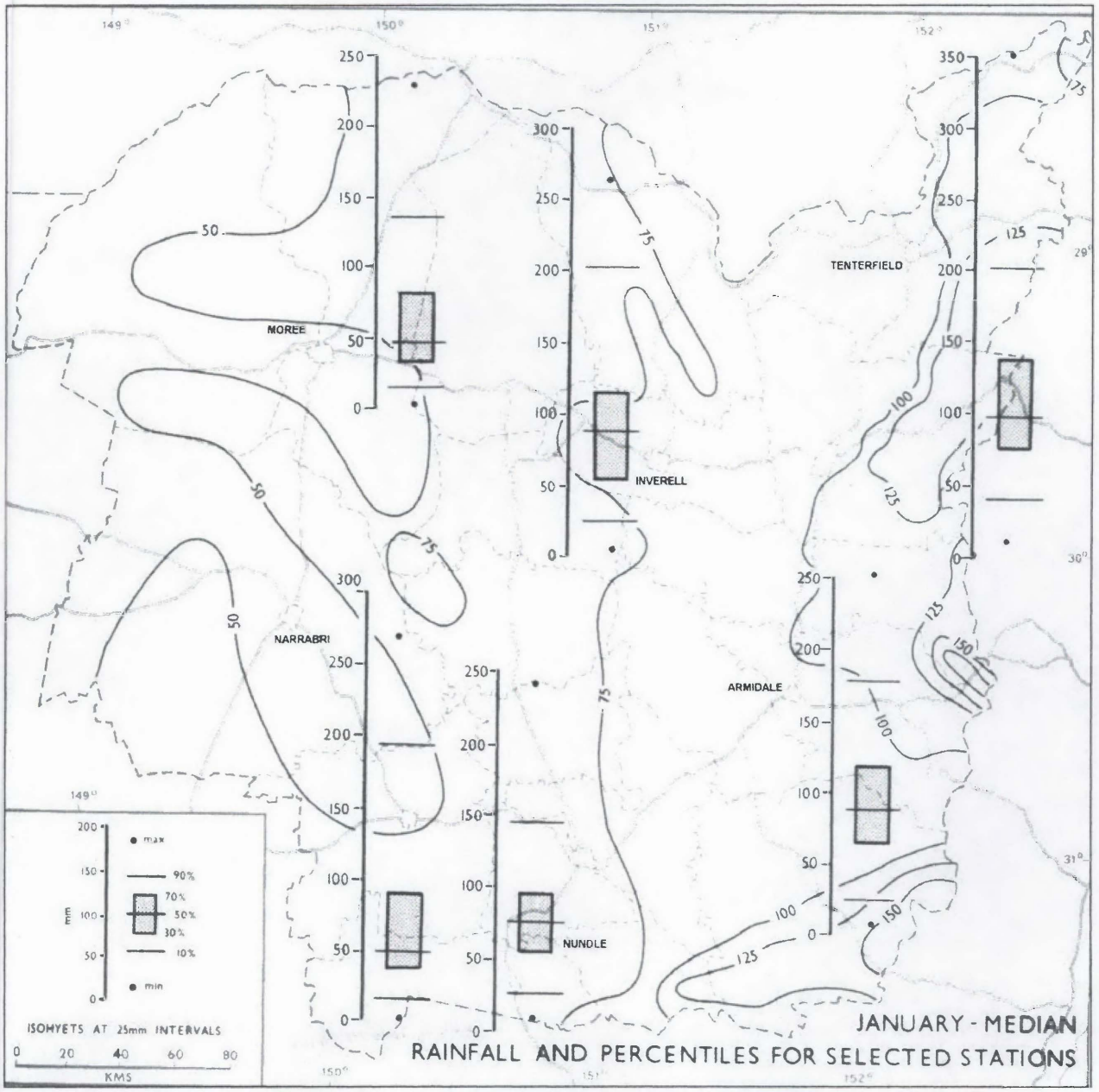
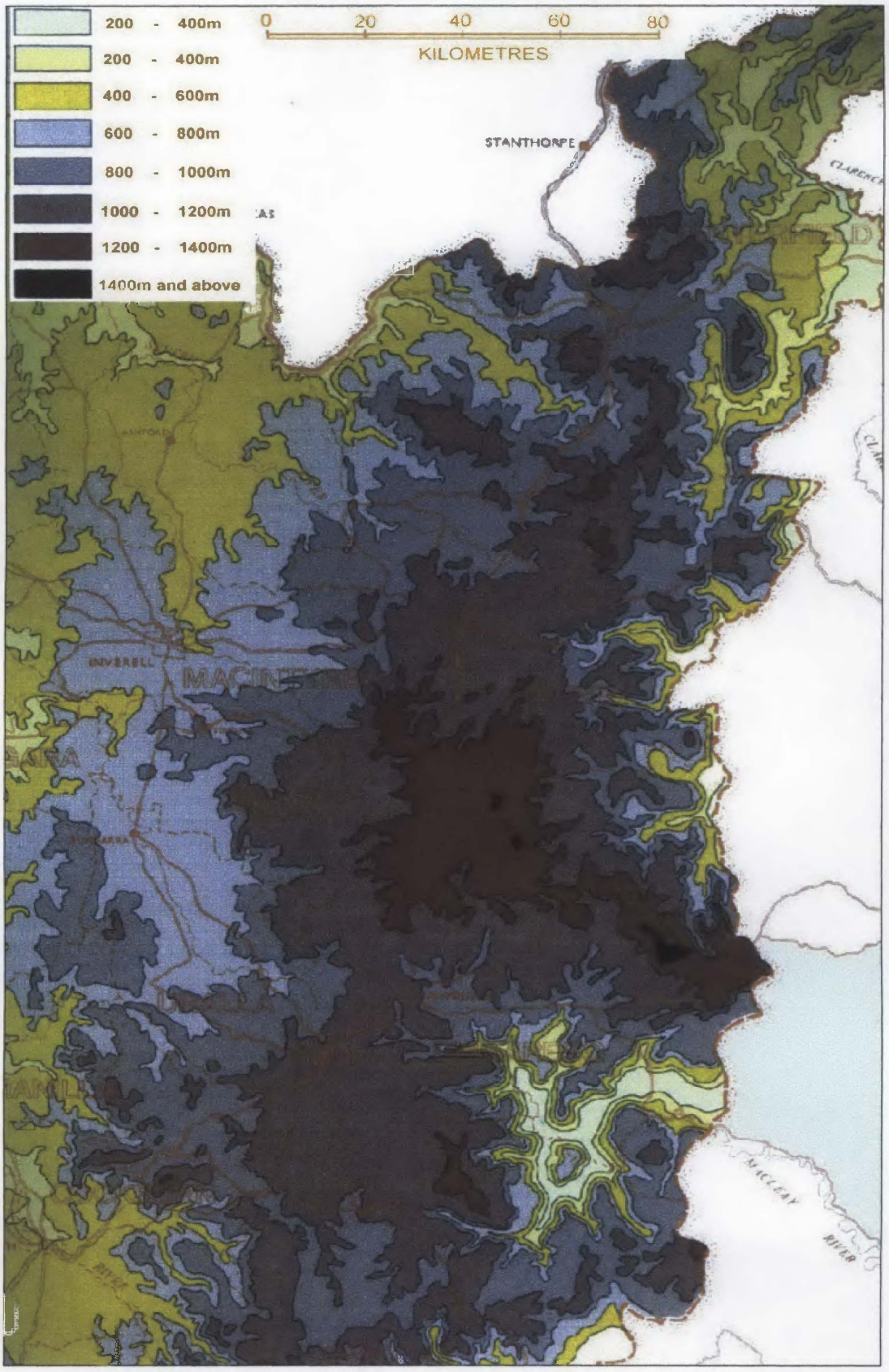


Figure 3.3. Median rainfall and percentiles for various places in the New England during the month of January (Source: Lea *et al.*, 1977).

3.2.9. Soils

The soil types found in the New England Tablelands include podsolics, solodics, red earths, euchrozems, chocolates, krasnozems, black earths and prairie soils (Map 3.3, Lea *et al.*, 1977). Their distribution and association depends, in the main, on parent material, climate and topography.

These soil types have been described extensively by Stace *et al.*, (1972). The following brief description of the soils found in the New England Tablelands was extracted from Stace *et al.*, (1972) and McGarity (1977). The podsolic soils are the



Map 3.2. Relief of the New England Tablelands (Source: Lea *et al.*, 1977).

most common in the New England Tablelands. These soils have a coarse texture (sandy loam) at the surface and a clay texture in the subsurface. Podsolic soils have developed from granite, metamorphic, and sedimentary rocks. Such soils vary in texture. The prevalent types have a B horizon colour of red, yellow or grey-brown depending on the sites drainage characteristics and rainfall. The podsolic soils are moderate to low in fertility because they are usually deficient in N, P, and S. The use of these soils is restricted due to their low moisture retention. These soils are acidic with surface pH varying from 4.5 to 5 .5.

The solodic soil types have sandy surface textures and clay textures in the subsoil with a distinct partition between the two. These soils are moderately fertile with a surface pH varying from 4.8 to 5.5 with a neutral to alkaline trend with depth. They can have sodium levels that result in surface crusting, tunnelling and gully erosion, particularly if they are cultivated.

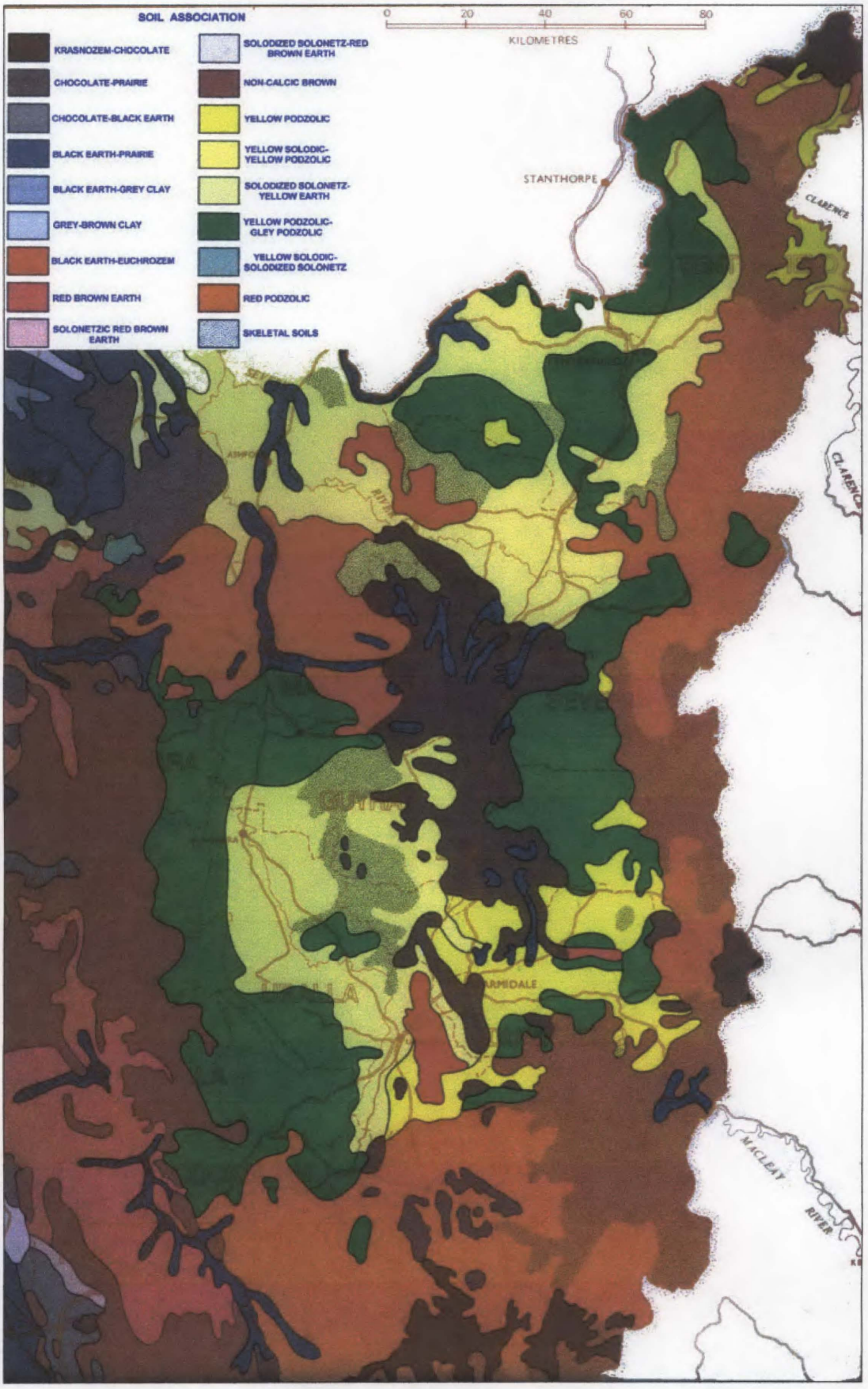
Euchrozems are red, strongly structured, clay soils. Apart from the A horizon, differentiation in other horizons is weak. The pH is essentially neutral in the surface soil. The soil pH increases gradually from 6.5 at the surface to 7.5 in the deep subsoil. These soils are used for grain crops such as wheat and sorghum.

The red earths have distinguishing characteristics of massive, predominantly sandy texture, porous and earthy soil materials and red-brown to red in colour. The profile has weak horizon differentiation except for the A horizon. Red earths vary greatly in properties. Most of them are acid, however, many others are neutral at the surface and become acid with the depth. Red earths are used for a variety of crops including cereals, vegetables and pastures.

The krasnozems are red, strongly structured, clay soils. These are very deep soils (610 cm) having weak horizon differentiation in the profile and the clay content increases with the depth. Surface soil pH is mildly acid but increases with the depth. pH values of 5.5 are common in the deep subsoil and on occasions are 4.5 or less. Because of the good physical properties and moderate to high fertility status, these soils are used for a wide range of agricultural and horticultural crops and pastures.

Chocolate soils are acid, friable clay loam and clay soils with weak to moderate horizon differentiation. These soils are moderately deep, mildly acid in the surface but less acidic at depth. Chocolate soils are moderate in fertility and are used for both pastures and cereals. Wheat is the major crop sown on such soils.

Black earths are heavy, dark grey, very dark brown or black soils with weak horizon differentiation. These soils are typically alkaline while some profiles are nearly



Map 3.3. Soils of the New England Tablelands (Source: Lea *et al.*, 1977).

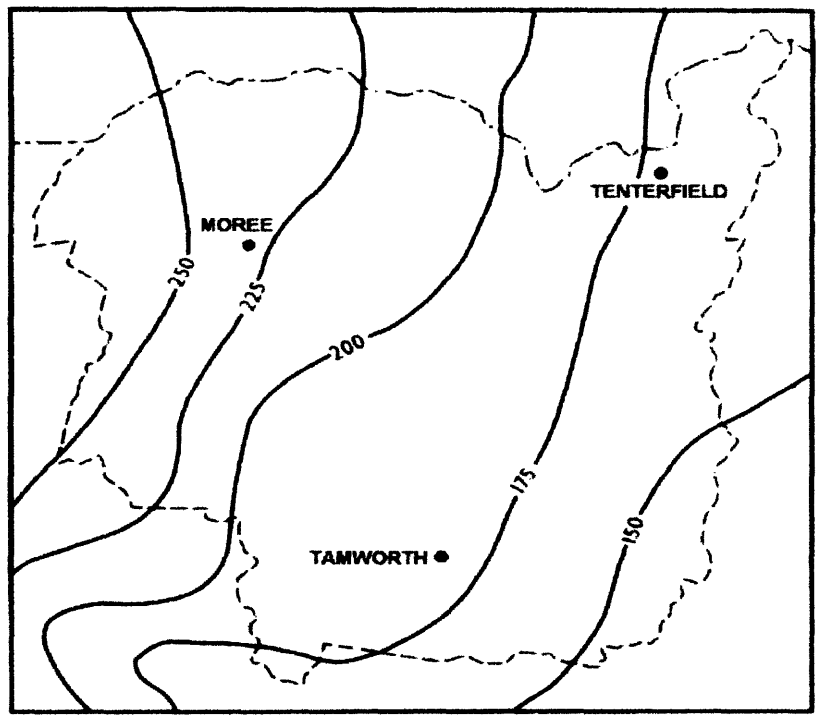


Figure 3.4. Average Monthly Evaporation (mm) (Australian Sunken Tank Values) (Source: Lea *et al.*, 1977).

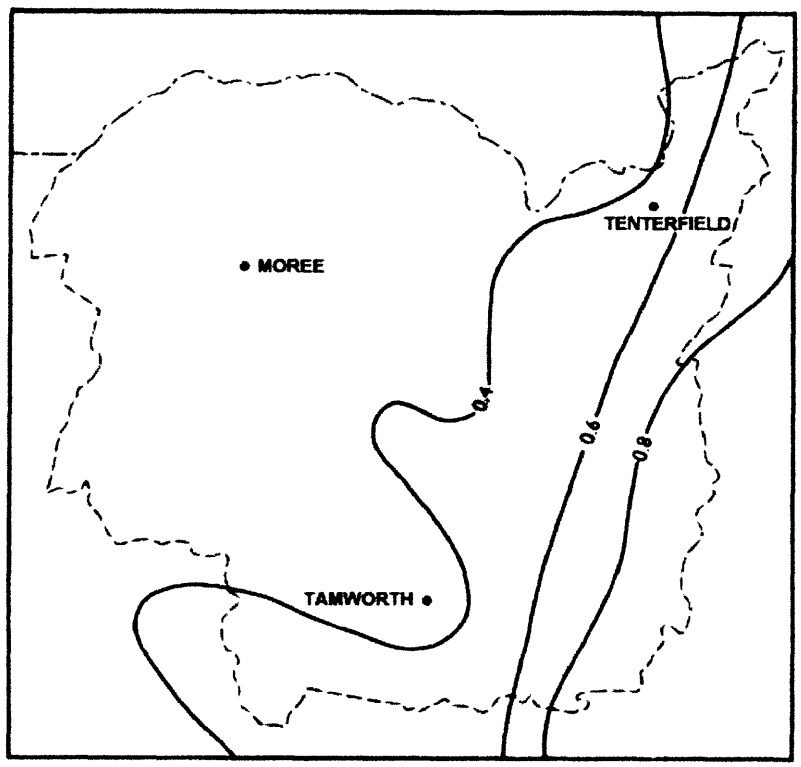


Figure 3.5. Average seasonal moisture index of New England (Source: Lea *et al.*, 1977).

neutral in the top 25 to 51 centimetres. Upon drying, such soils produced deep cracks, while upon wetting, they are very plastic and extremely sticky. Black earths are used for

grazing and for a wide range of crops mainly for grain production. These soils have limited extent on the Tablelands.

As described in Chapter-2, the cultivation of buckwheat is best suited to well-drained, medium textured soils including sandy loam, loam and silt loam soils (Marshall, 1969; Campbell and Gubbels, 1979; Tahir and Farooq, 1988; Myers and Meinke, 1994; Park, 1998; Bjorkman, 1998). However, its cultivation is not restricted to such soils. It is often grown on heavy soils as well (Campbell and Gubbels, 1979). Indeed, productivity is often better in heavy soil than light soils because of a decrease in lodging due to the good support that soil provides under conditions of high wind (Ruszkowski and Zebrowski, 1982).

The cultivation of buckwheat on poorly drained, saturated and marshy soils is not recommended (Marshall, 1969; Campbell and Gubbels, 1979; Narian, 1983; Myers and Meinke, 1994; Taylor, 1996).

Buckwheat has a higher tolerance to soil acidity (Robinson, 1980; Myers and Meinke, 1994) than any other grain crop (Marshall, 1969; Choi *et al.,* 1995; Bjorkman, 1998). It also responds to liming on soils below pH 5.0 (Robinson, 1980; Schmidt, 1995). Similarly, although buckwheat performs better on infertile soils than most grains, it does even better when fertilisers are added.

Based on the soil requirement of buckwheat, and the information on the soil types found in the New England Tablelands, it can be concluded that buckwheat can be grown in the soils of this region provided the required management practices are fulfilled.

3.2.10. Slope

Slope is one of the most important characteristics of the soil. Soil depth, soil moisture, drainage, and potential for erosion are closely related to the slope. Generally, most of the cultivated area in the New England Tablelands is on gentle slopes with the exception of some areas in the Tenterfield district (Map 3.4, Lea *et al.*, 1977). According to the general relationship between slopes, soils and land surface capability, soils on the gentle slopes have moderate depth and are usually mature, finer textured, and moderately well drained (Swan, 1977). These soils have moderate erosion risk and are used for grazing and cultivation purposes with erosion control measures, especially on long slopes.

3.2.11. Soil erosion

The soil erosion of the area is classified into four main classes of erosion, i.e. Class 1 - no appreciable erosion, class 2 – sheet erosion – range slight to moderate with local severe sheet erosion and rilling, class 3 – gully erosion – range from 10 percent to 30 percent of drainage lines gullied and class 4 – severe local gullying.

A significant part of the New England Tablelands area is affected by all the classes except class-4, which has affected a minor area of the Tablelands (Map 3.5 Lea *et al.*, 1977).

Soil erosion control is necessary for sustained yields. Due to the shallow rooting system and sensitivity to water-logging of buckwheat, it is important that it should be cultivated on a gentle slope and on soils with a good drainage system. Although some of the soils, e.g. duplex soils, may not have a high moisture retention capacity, the large surface area of buckwheat leaves can minimise evaporation losses from the soil surface. The cultivation of buckwheat can also help in minimising the impact of raindrop erosion due to covering of the soil surface.

Map 3.4. Slope classification of the New England Tablelands (Source: Lea *et al.*, 1977).

Map 3. 5. Soil erosion in the New England Tablelands (Source: Lea *et al.*, 1977).

3.3. SUMMARY

Within the arable lands of New England Tablelands there are areas which are suitable for buckwheat production because of their favourable conditions of climate, soil types and topography. During the growing season of buckwheat (December to March) mean maximum and minimum temperatures range from 21.8°C to 30.3°C and 9.2 °C and 16.4 °C. It is only at regular temperatures above 30 °C when conditions are dry that seed formation and flowering are adversely affected. Frosts, which can be devastating to buckwheat, are very rare and are limited to some places around Walcha.

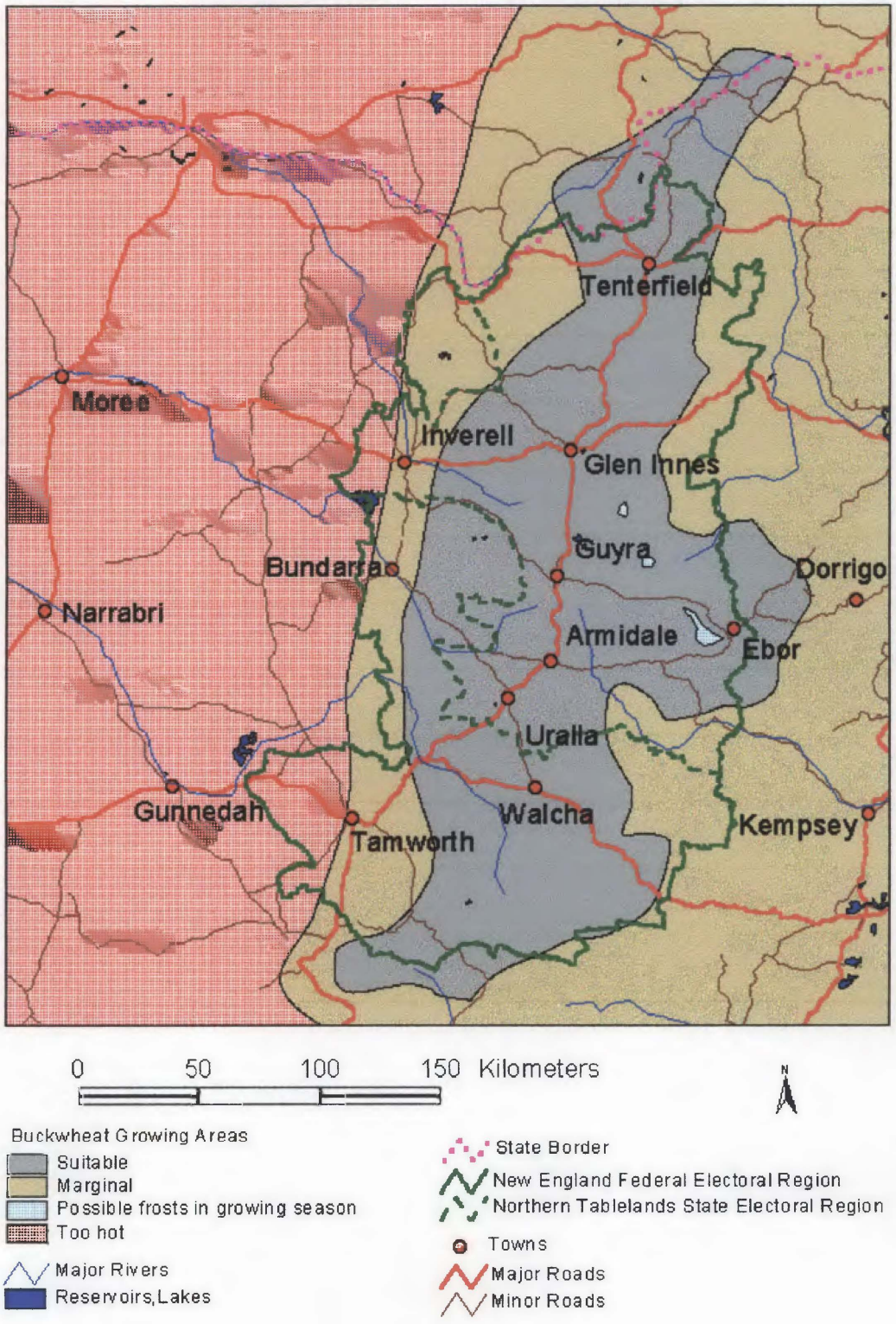
In this predominantly summer rainfall area, precipitation is generally adequate, with December to March median totals ranging from 281-347 mm or around 300 mm from December – March with more than half falling in December and January.

Temperature and moisture stress are moderated by the altitude of the Tablelands area. The great majority of which lies between 800 and 1200 metres. Thus in the buckwheat growing areas of the New England Tablelands the summer moisture indices are satisfactory (approximately 0.6).

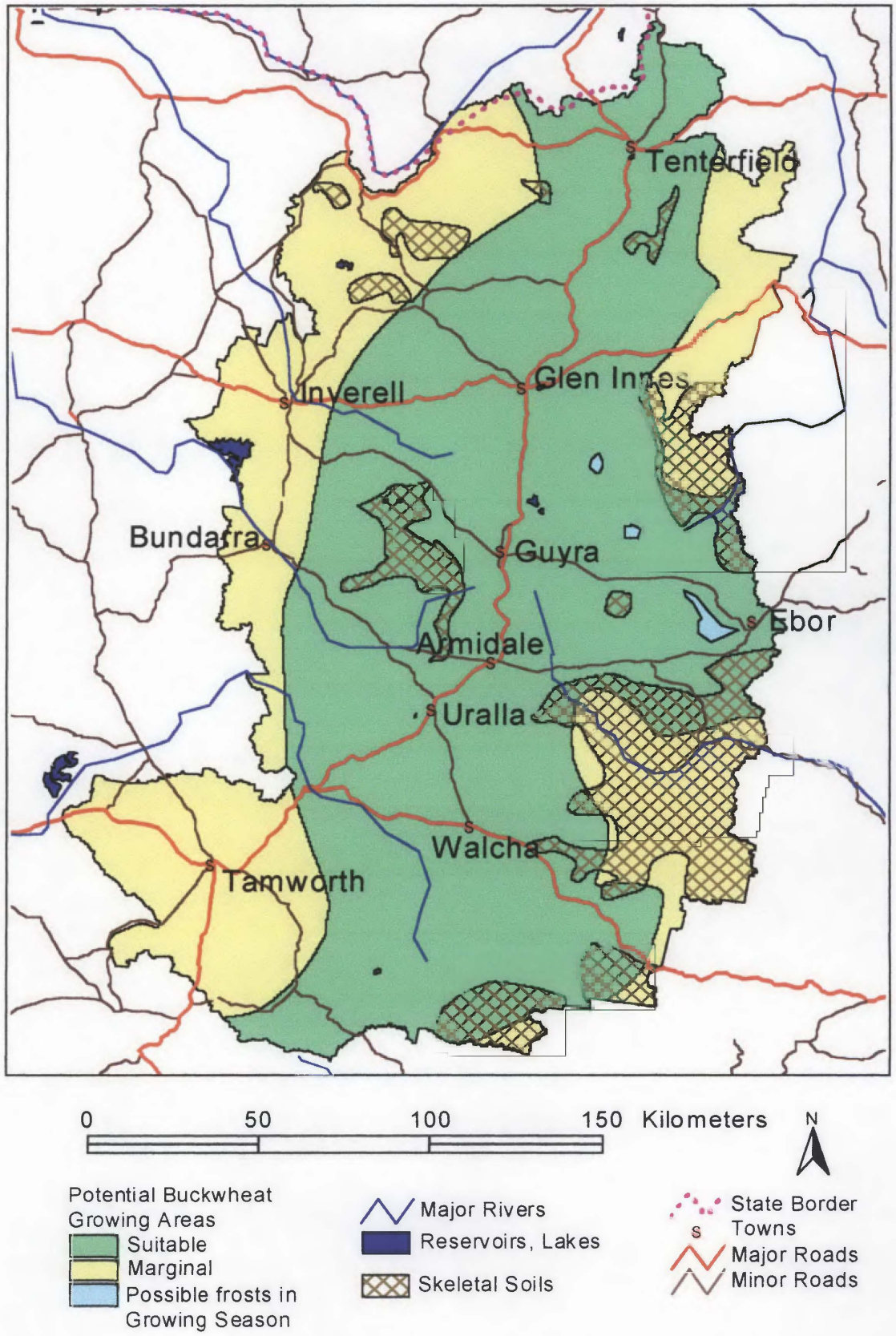
There is a diversity of soil types in New England Tablelands including podsolic, solodics, red earths, euchrozems, chocolates, krasnozems, black earths and prairie soils, most of which are suitable for buckwheat production, particularly if they are managed appropriately. The parts of the New England Tablelands which are suitable for buckwheat by virtue of climate and soil, are generally of a gentle gradient, thus allowing convenient cultivation by machinery and a limited need for erosion control.

Map 3.6 shows the areas of the New England Tablelands that are climatically and topographically suitable for the cultivation of buckwheat. The boundaries are generalised and should not be regarded as definitive due to the low resolution of the original maps in the Atlas of New England (Lea *et al.*, 1977). There would be also some local exceptions due to factors like erosion, and slope of the land that should be considered before growing buckwheat within this area. Some of the land within the suitable areas may not be appropriate for buckwheat cultivation because of the existence of skeletal soils on the steep slopes with very shallow depths as indicated in the Map 3.7. Places on the coast, to the east (Kempsey, Coffs Harbour, and Port Macquarie) may have suitable temperature regimes but may not be suitable due to high mean monthly rainfall and the high number of mean rain days during the buckwheat growing season which may affect lodging and ability to harvest. Places to the west (Moree, Narrabri, Gunnedah) have many days with a temperature in excess of 35°C and are therefore unsuitable for growing buckwheat. Before any decision is made on the

potential of any area for cultivating buckwheat, detailed studies of the factors discussed in this Chapter are necessary for each location. There are likely to be localised areas in the region classified as suitable which will prove to be marginal or even unsuitable after detailed analysis of the relevant parameters and vice versa.



Map 3.6. Climatically suitable areas of the New England for the cultivation of buckwheat.



Map 3.7. Climatically suitable areas of the New England Tablelands for the cultivation of buckwheat, also included are areas of severe soil limitations.