Chapter 6. Soil Physical and Chemical Properties

6.1 Soil Profile

6.1.1 Depth of Horizon A

Depth of Horizon A was measured at 260 points across 79 sites. Results are summarised in Table 6.1. Average depth shows a decreasing trend from Group 1 to 3.

Table 6.1 Depth of Horizon A

Soil Group	No. of Points	Depth of Horizon A (mm)						
		Average	Std.	Min.	Max.	Percentile		
						25	50	75
1	30	196	42	140	320	170	185	230
2	72	185	36	130	290	160	185	210
3	86	170	36	100	290	150	170	190
4	34	186	65	120	340	150	160	210
5	16	176	29	130	230	155	170	200
6	22	190	34	100	240	180	200	210

Note: Std. = standard deviation, Min. = minimum, Max. = maximum.

Figure 6.1 is a box and whisker plot of depth of Horizon A. Median values of depth of Horizon A show a decreasing trend from Group 1 to 4. The band between upper and lower quartiles are relatively narrow to suggest that average values could be used as indicative values for the respective soil types for practical applications. Depth of Horizon A of 34 soil types is presented in Table 6.2.

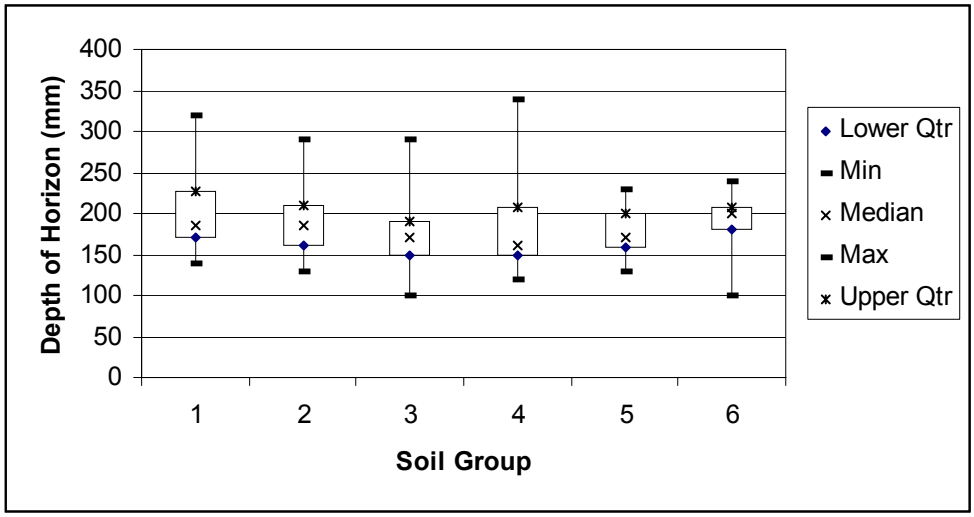

Figure 6.1 Depth of Horizon A of Soil Groups

Table 6.2 Depth of Horizon A of Soil Types

Irrigation District	Soil Group	Soil Type	No of Sampling Points	Depth of Horizon A (mm)						
				Mean	Std.	Min.	Max.	Percentile		
								25	50	75
MV	1	Cobram sandy loam & Ss	2	260		200	320			
	2	Waaia loam	10	151	27	130	200	130	140	160
	2	Waaia loam phase	4	175	21	150	200	160	175	190
	2	Cobram loam	12	192	24	150	220	170	200	210
	2	Moira loam friable phase	10	205	37	150	280	190	200	230
	3	Moira loam	2	210		190	230			
	3	Naring loam	8	160	19	130	180	145	165	175
	5	Ulupna clay	2	140		130	150			
	6	Muckatah clay loam	6	217	16	200	240	200	215	230
	6	Boosey loam friable phase	4	168	25	140	200	150	165	185
	6	Boosey loam	2	185		180	190			
GV	1	East Shepparton fine sandy loam	14	196	36	150	250	170	185	240
	2	Katamatite loam	4	220	22	200	250	205	215	235
	2	Shepparton fine sandy loam	14	176	25	140	220	150	175	190
	3	Lemnos loam friable phase	8	179	57	100	280	135	190	200
	3	Lemnos loam semi friable phase	4	203	19	190	230	190	195	215
	3	Lemnos loam	38	166	34	100	290	150	165	180
	3	Goulburn loam friable phase	4	195	17	180	220	185	190	205
	4	Goulburn loam	20	187	64	130	340	150	155	200
	4	Goulburn clay loam	4	283	22	260	310	265	280	300
	5	Congupna clay loam	6	207	12	200	230	200	200	210
	6	Congupna clay	4	195	13	180	210	185	195	205
RO	1	Nanneella fine sandy loam	14	186	37	140	260	150	175	220
	2	Timmering loam	18	191	42	130	290	160	185	210
	3	Wanalta loam	22	162	38	100	262	140	160	180
	4	Wana loam	2	120		120	120			
	4	Koyuga clay loam	4	135	17	120	160	125	130	145
	4	Koga clay loam	4	173	21	150	200	160	170	185
	5	Rochester clay	2	160		150	170			
	5	Alta clay loam	6	162	16	130	170	160	170	170
	6	Wallenjoe clay	2	120		100	140			
	6	Carag clay	4	205	25	180	240	190	200	220

6.1.2 Depth of Horizon B1

Depth of Horizon B1 was measured at 133 points across 50 sites. Results are summarised in Table 6.3.

Table 6.3 Depth of Horizon B1

Soil Group	No. of Points	Depth of Horizon B1 (mm)						
		Average	Std.	Min.	Max.	Percentile		
						25	50	75
1	20	188	58	110	320	150	175	220
2	40	192	55	100	310	155	180	230
3	39	161	44	60	250	130	160	198
4	16	191	51	120	320	155	190	220
5	8	165	34	110	210	145	160	195
6	10	198	41	120	270	180	200	220

Figure 6.2 is a box and whisker plot of depth of Horizon B1. The bands between upper and lower quartiles are relatively narrow to suggest that average values could be used as indicative values for the respective soil types for practical applications.

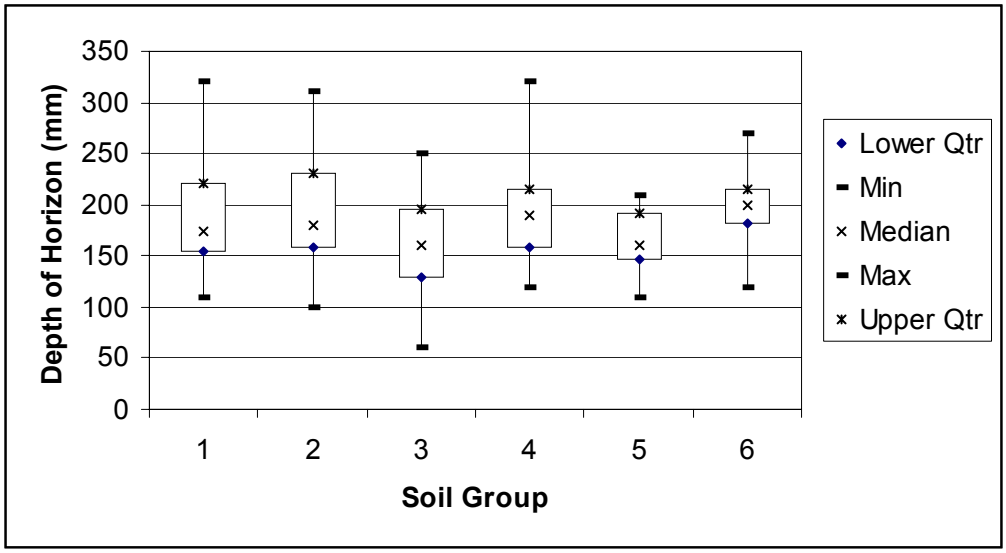

Figure 6.2 Depth of Horizon B1 of Soil Groups

6.2 Soil Texture

6.2.1 Soil Texture of Published Soil Surveys

The published soil maps from previous surveys (conducted by Skene and Poutsma in the 1960s) of the Goulburn Valley (GV) and Rochester (RO) districts did not specify the soil texture classification used. Using the previous survey's particle size distribution of the Horizon A, the soil texture was calculated using the USDA and Australian texture schemes. The result of analysis is presented in Table 6.4 and 6.5. While the texture determined from the USDA scheme is quite similar to the existing name of major soil types, the Australian scheme is mostly different. The

results suggest that the USDA classification scheme was used for texture analysis in the previous soil surveys. USDA soil texture classification system was therefore used in this project for the determination of soil particle size distribution.

Table 6.4 Soil Texture of Published Soil Data of Goulburn Valley

Soil Group	Soil Type	Horizon A			Texture	
		Clay %	Silt %	Sand %	USDA	Australian
1	East Shepparton fine sandy loam	13.5	22.5	62.5	Sandy loam	Loamy sand
2	Shepparton fine sandy loam	14.5	25.5	58.5	Sandy loam	Silty loam
3	Lemnos loam	27	35.8	34.4	Loam	Silty loam
4	Goulburn loam	27.25	26.5	45	Loam	Silty loam
5	Congupna clay loam	36	21	40	Clay loam	Clay loam
6	Congupna clay	51	22	23	Clay	Silty clay

Table 6.5 Soil Texture of Published Soil Data of Rochester District

Soil Group	Soil Type	Horizon A			Texture	
		Clay %	Silt %	Sand %	USDA	Australian
1	Nanneella fine sandy loam	12.67	22.00	63.33	Sandy loam	Loamy sand
2	Timmering loam	17.00	28.00	52.25	Sandy loam	Silty loam
3	Wanalta loam	20.75	30.25	46.75	Loam	Silty loam
4	Koga clay loam	33.20	26.00	38.20	Clay loam	Silty clay loam
5	Rochester clay	50.67	18.33	28.33	Clay	Clay
6	Carag clay	62.00	17.50	17.00	Clay	Clay

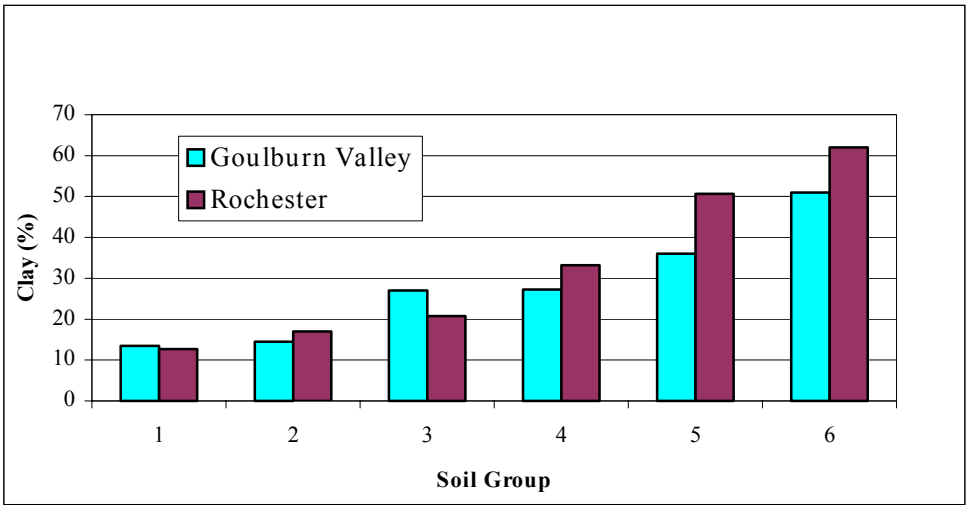

Figure 6.3 Clay Percentage in Horizon A of Published Survey Data

Figure 6.3 shows clay percentage in Horizon A for soil group calculated using data from the published soil survey. The graph shows the increasing trend of clay % from Group 1 to Group 6 for both regions.

6.2.2 Soil Texture of Horizon A

Soil particle size distribution of Horizon A was measured at 348 points across 79 sites. Results are summarised in Table 6.6. Average clay content increases from Group 1 to Group 5 with little difference between Groups 5 and 6. On the other hand, average sand content decreases from Group 1 to 6.

Table 6.6 Soil Texture of Horizon A

Soil Group	No of Sampling Points	Particle Size Distribution*					
		Clay %		Silt %		Sand %	
		Average	Std**	Average	Std	Average	Std
1	78	11.2	8.7	35.4	10.6	53.4	14.8
2	112	13.7	6.0	35.0	7.4	51.3	10.2
3	86	19.8	8.9	35.6	8.3	44.6	11.7
4	34	20.6	11.3	39.0	5.9	40.4	10.8
5	16	32.5	13.3	30.6	4.9	36.9	12.3
6	22	29.1	13.7	34.6	6.9	36.3	12.6

Note: * Particle size limit: clay < 2 μm, silt 2-50μm, sand 50-2000 μm; ** Std = standard deviation

Figure 6.4 shows distribution of particle size plotted in the USDA texture triangle. Particle size distribution of Horizon A covers a large range of soil texture such as sand, loamy sand, sandy loam, loam, silty loam, clay loam, silty clay loam, sandy loam and clay. However, most of data are concentrated on sandy loam, loam and clay loam.

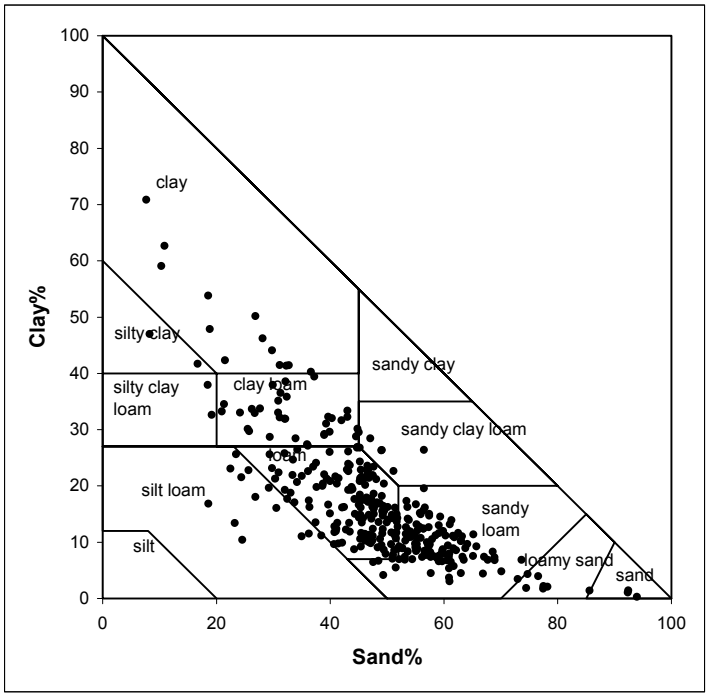

Figure 6.4 Soil Particle Size Distribution of Horizon A

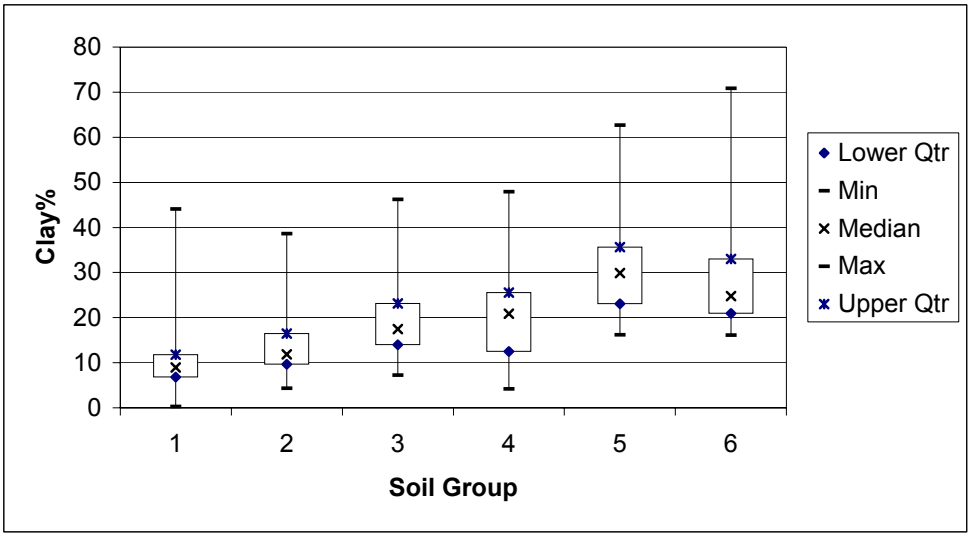

Figure 6.5 Clay Content of Horizon A

Figure 6.5 is a box and whisker plot of clay content of Horizon A. Despite the clay percentage of each soil group being distributed over a large range, the bands between upper and lower quartiles are relatively narrow. Clay percentages of Groups 3 and 4 are not significantly different when their means are compared in a t-test. The same is found for Groups 5 and 6

Figure 6.6 is a box and whisker plot of sand content of Horizon A. Median values show a decreasing trend with soil group. Despite sand percentage of each soil group being distributed over a large range, the bands between upper and lower quartiles are relatively narrow for most of soil groups. Sand percentages of Groups 4, 5 and 6 are not significantly different when their means are compared in t-tests.

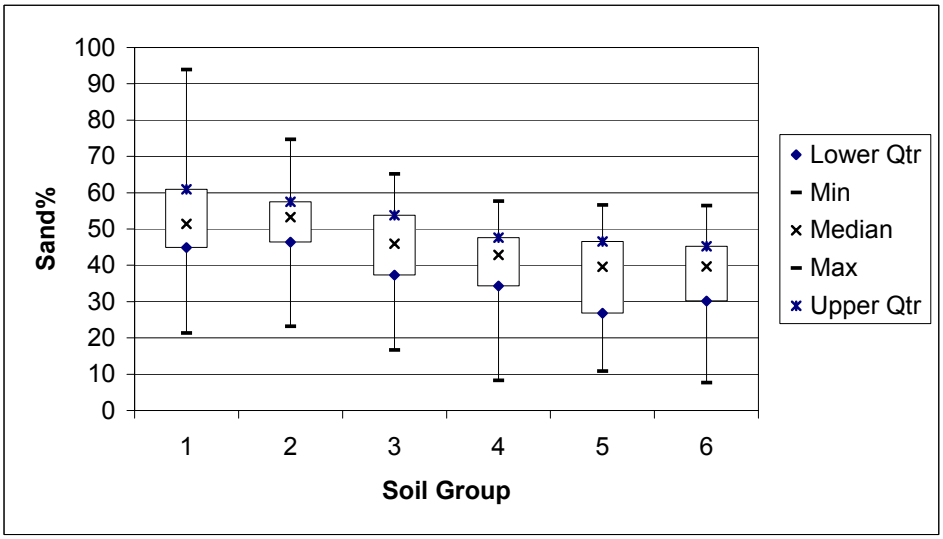

Figure 6.6 Sand Content of Horizon A

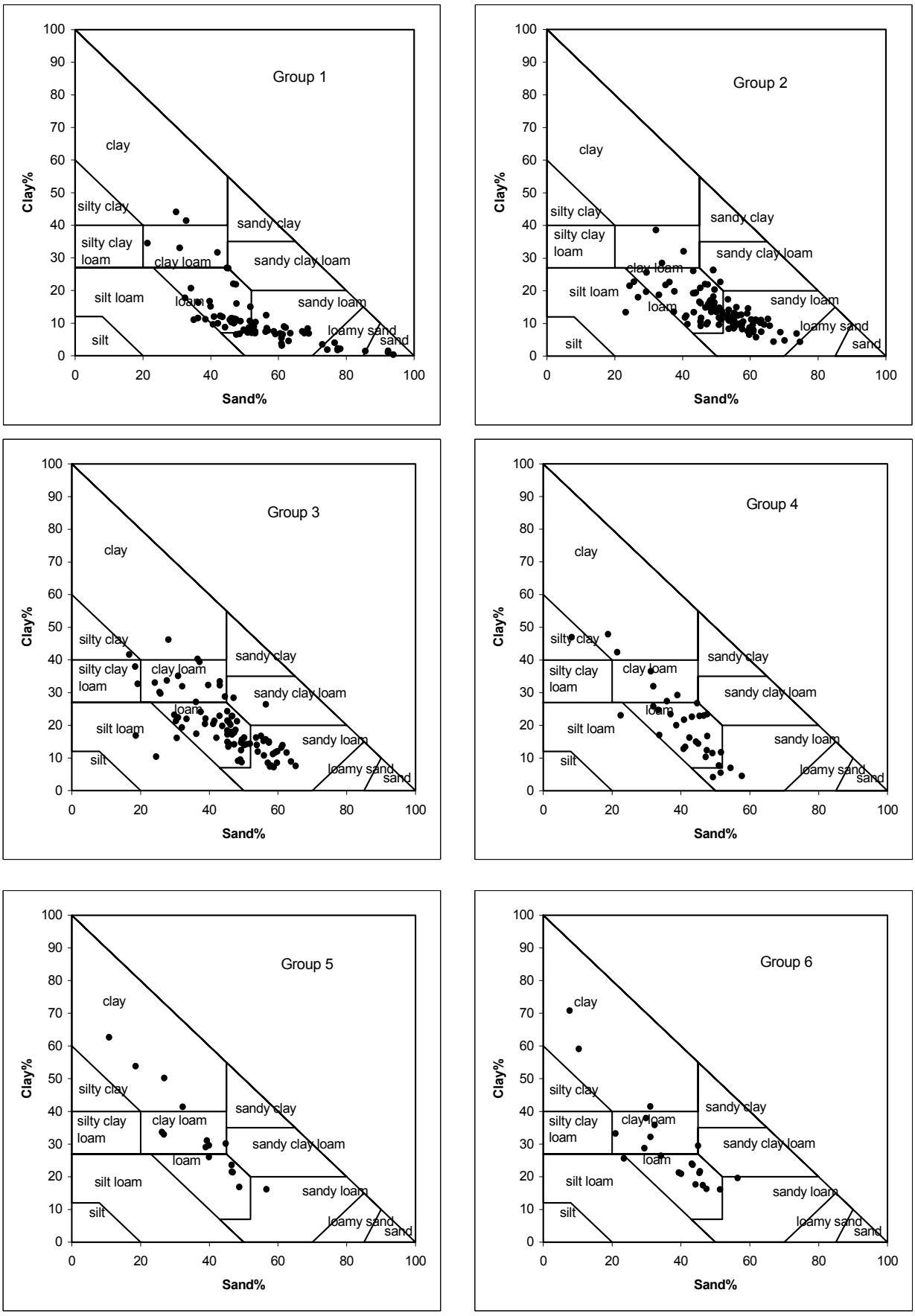

Figure 6.7 Soil Particle Size Distribution Data of Sampling Points from 79 Sites (Horizon A)

Figure 6.7 shows particle size distributions of Horizon A of soil groups on the USDA texture triangle. For Groups 1, 2, and 3, particles are concentrated mainly on sandy loam and loam texture. For Groups 3 and 4, particles are concentrated on sandy loam, loam and clay loam. For Groups 5 and 6, particles are concentrated on loam, clay loam and clay. It shows that texture is slowly changing with soil group. Groups 2, 3 and 4 cannot be clearly distinguished from each other based on soil texture of Horizon A, nor can Groups 5 and 6 be distinguished from each other.

Figure 6.8 shows the comparison of average clay content of Horizon A of soil groups between three irrigation districts (MV, GV, RO) of the SIR. MV district has no soil type under Group 4 in existing soil maps. Soils of Group 6 in RO district appear to have higher clay % compared to those in the GV and MV districts. Average clay content of Groups 2 and 3 is not much different among three districts. It appears that Groups 4 and 5 of GV district have low clay content compared to those of other districts. On the other hand, soils of Group 1 of GV district appear to have higher clay content compared to those of other districts.

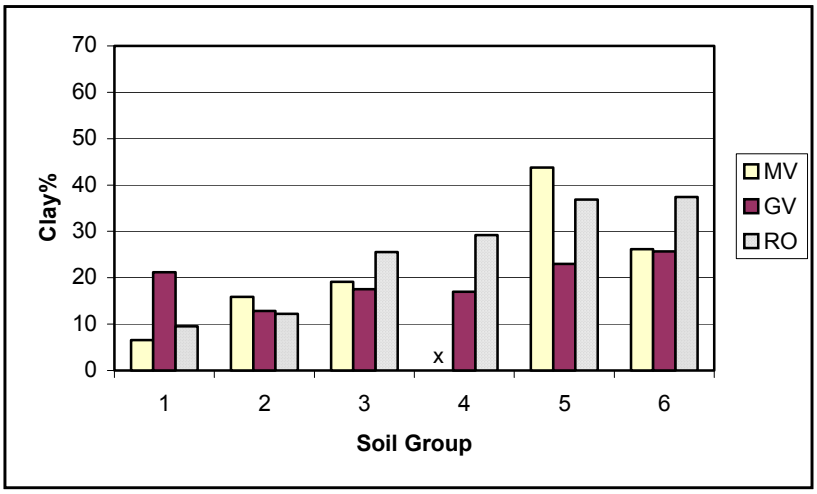

Figure 6.8 Average Clay Content of Horizon A in GV, MV, RO Districts

Table 6.7 lists measured clay content of Horizon A of 34 soil types. To understand the variability of clay content between and within soil types, the distribution of clay content of selected soil types is plotted in Figure 6.9. It appears that the variation in clay content within some soil types may be as much as that within their soil groups. On the other hand, some soil types have narrow bands between upper and lower quartiles and are well defined. There is also a large variability of clay content between soil types in some soil groups. In Group 1, for example, Ss and Ssp soil types are significantly different from ESfsl and Nfsl. Therefore, within-group-variability of clay content is due to both between-soil-type variability and within-soil-type variability.

Table 6.7 Clay Content in Horizon A

Irrigation District	Soil Group	Soil Type	No. of Sampling Points	Clay (%)						
				Mean	Std.	Min.	Max.	Percentile		
								25	50	75
MV	1	Sandmount sand	4	1.1	0.5	0.3	1.5	0.7	1.2	1.4
	1	Sandmount sand phase	4	2.0	0.2	1.8	2.2	1.8	2.0	2.2
	1	Cobram sandy loam & Ss	2	26.9		26.8	26.9			
	2	Waaia loam	10	14.5	5.8	7.3	26.4	10.6	13.2	19.4
	2	Waaia loam phase	4	9.3	1.9	6.9	11.4	8.1	9.5	10.5
	2	Cobram loam	12	18.1	9.2	4.8	38.6	11.0	17.8	23.5
	2	Moira loam friable phase	10	17.2	7.2	9.6	32.0	11.5	14.6	22.1
	3	Moira loam	2	11.1		7.2	15.0			
	3	Naring loam	8	21.1	6.6	13.9	32.3	15.9	19.5	25.9
	5	Ulupna clay	2	43.8		33.7	53.8			
	6	Muckatah clay loam	6	31.0	7.3	21.3	41.5	25.6	31.0	35.8
	6	Boosey loam friable phase	4	19.4	3.9	16.1	24.0	16.2	18.8	22.6
	6	Boosey loam	2	24.9		17.7	32.2			
GV	1	East Shepparton fine sandy loam	14	21.2	13.3	3.5	44.1	10.6	17.2	33.1
	2	Katamatite loam	4	11.7	2.0	10.2	14.6	10.4	10.9	12.9
	2	Shepparton fine sandy loam	54	12.9	4.6	4.4	25.6	9.5	11.9	16.2
	3	Lemnos loam friable phase	8	19.9	5.8	14.3	32.3	15.9	18.3	22.2
	3	Lemnos loam semi friable phase	4	9.1	1.9	7.6	11.9	8.0	8.5	10.2
	3	Lemnos loam	38	18.0	8.3	7.4	41.7	11.6	16.2	21.9
	3	Goulburn loam friable phase	4	17.1	4.3	12.0	21.0	13.6	17.7	20.6
	4	Goulburn loam	20	17.7	9.6	4.2	36.5	9.0	16.9	24.1
	4	Goulburn clay loam	4	13.6	2.1	11.5	16.3	12.0	13.4	15.3
	5	Congupna clay loam	6	23.0	6.7	16.2	33.0	16.9	21.5	29.1
	6	Congupna clay	4	25.7	9.0	17.4	38.0	19.1	23.7	32.2
RO	1	Nanneella fine sandy loam	54	9.5	3.7	3.1	22.1	6.9	8.9	11.2
	2	Timmering loam	18	12.3	5.9	4.4	28.5	8.5	11.3	13.4
	3	Wanalta loam	22	25.5	9.9	9.1	46.2	17.4	22.6	33.7
	4	Wana loam	2	45.1		42.3	47.9			
	4	Koyuga clay loam	4	20.9	5.8	13.4	27.4	16.7	21.3	25.0
	4	Koga clay loam	4	29.6	11.8	21.7	47.0	22.4	24.9	36.9
	5	Rochester clay	2	45.8		41.4	50.2			
	5	Alta clay loam	6	33.9	14.4	23.6	62.7	26.0	29.9	31.1
	6	Wallenjoe clay	2	65.0		59.1	70.8			
	6	Carag clay	4	23.6	4.3	19.6	29.5	20.6	22.7	26.6

The variability of clay content within paddock was measured on seven paddocks, each present as a uniform soil type in the SIR soil maps, and one mixed paddock presents as consisting of four soil types. The mixed paddock had soil types of three different soil groups; Cobram sandy loam (Csl) from Group 1, Moira loam friable phase (Mlfp), Waaia loam (Wal) from Group 2, and Naring loam (Nl) from Group 3. Paddocks of multiple soil types are commonly found in the MV District as soil types in MV district have smaller area in one consolidate block compared to those of other districts. The purpose of measuring a mixed paddock was to examine the effect of soil types on within-paddock variability. Figure 6.10 shows the within-paddock variability of clay content

measured on uniformly mapped soil types and mixed soil types. Comparison of Figures 6.9 and 6.10 shows that a single paddock of uniformly mapped soil type covers a large part of variability of clay content within soil type between lower and upper quartiles. Within-paddock variability of clay content of a mixed paddock containing four soil types is comparable to that of a paddock of uniformly mapped soil type.

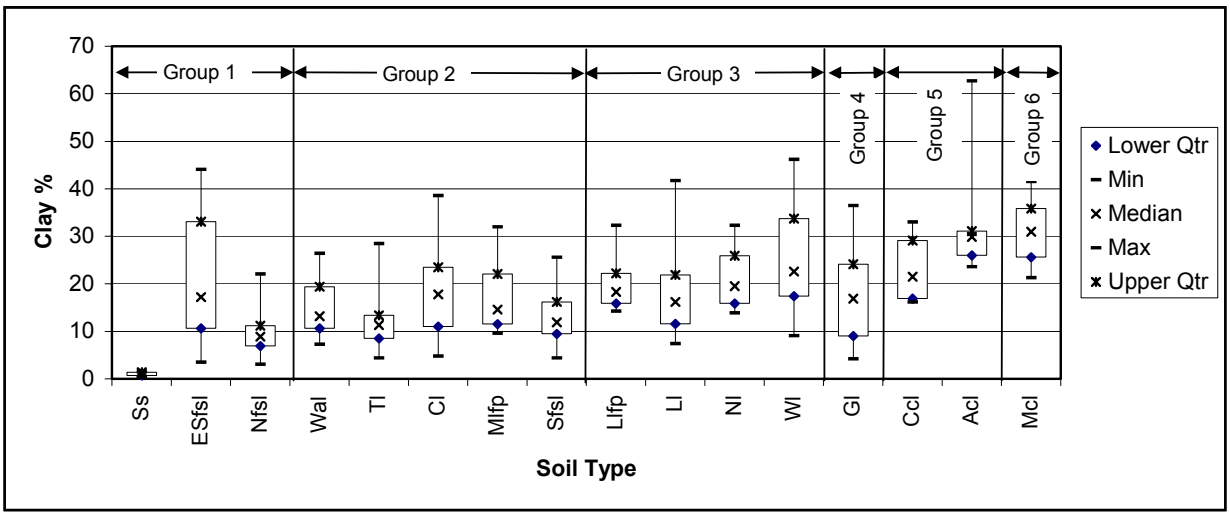

Figure 6.9 Clay Content of Soil Types (Horizon A)

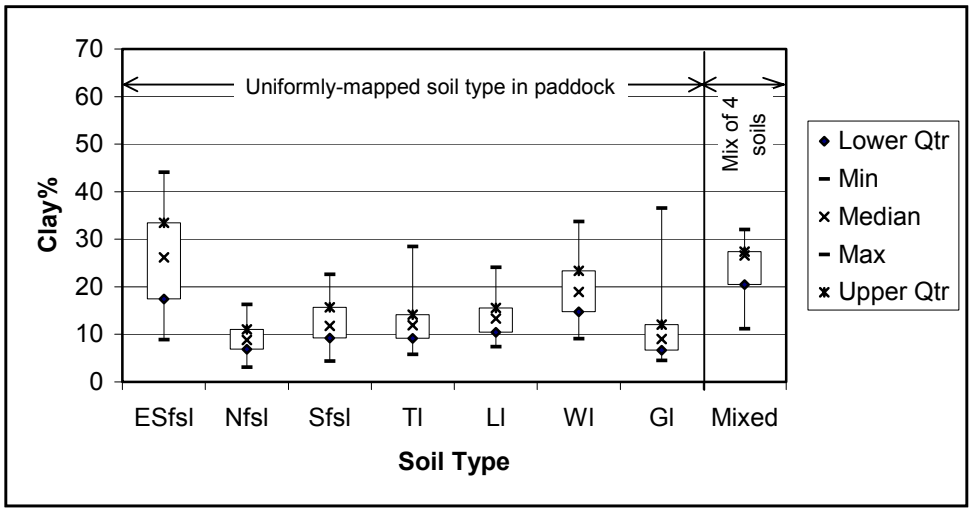

Figure 6.10 Paddock Scale Variability of Clay Content of Horizon A

6.2.3 Soil Texture of Horizon B1

Soil texture of Horizon B1 was measured at 347 points across 79 sites. Results are summarised in Table 6.8. Average clay contents of Groups 2, 3, 4 are not much different. Similar to Horizon A, Group 5 has the highest average clay content among soil groups.

Table 6.8 Soil Texture of Horizon B1

Soil Group	No of Points	Particle Size Distribution*					
		Clay %		Silt %		Sand %	
		Average	Std	Average	Std	Average	Std
1	78	27.0	11.5	38.7	12.9	34.2	19.8
2	112	38.7	12.4	31.7	8.1	29.6	12.3
3	85	42.3	14.2	30.5	10.3	27.3	11.2
4	34	37.3	13.7	36.2	6.8	26.6	10.6
5	16	55.1	12.4	25.0	8.0	19.8	7.4
6	22	46.9	12.3	29.3	8.3	23.8	8.8

Note: * Particle size limit: clay < 2 μm, silt 2-50 μm, sand 50-2000 μm.

Figure 6.11 shows distribution of particle size plotted on the USDA texture triangle. Particle size distribution of Horizon B1 covers large variety of soil texture such as sand, sandy loam, loam, silty loam, clay loam, silty clay loam, silty clay and clay. However, most of data are concentrated on loam, clay loam and clay.

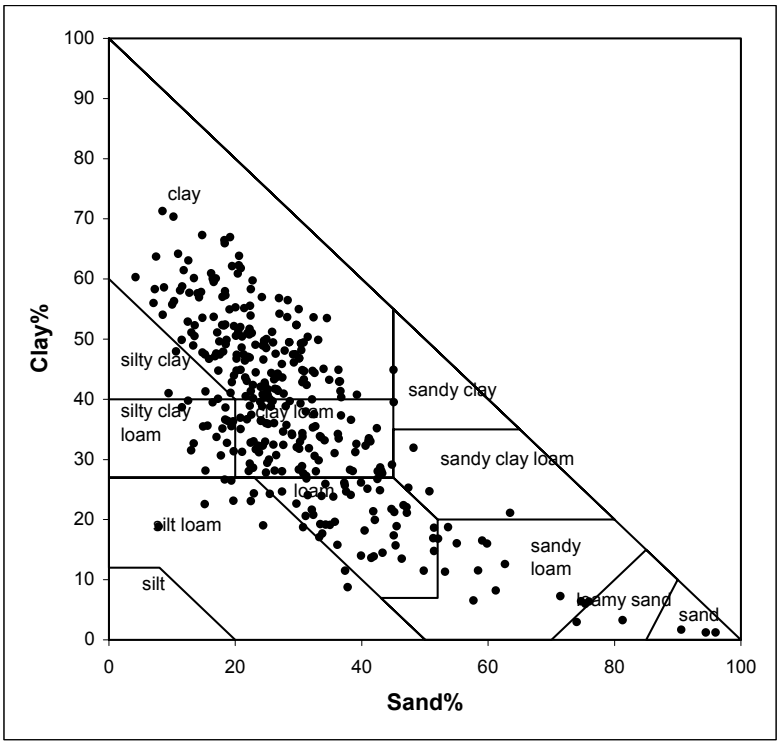

Figure 6.11 Particle Size Distribution of Horizon B1

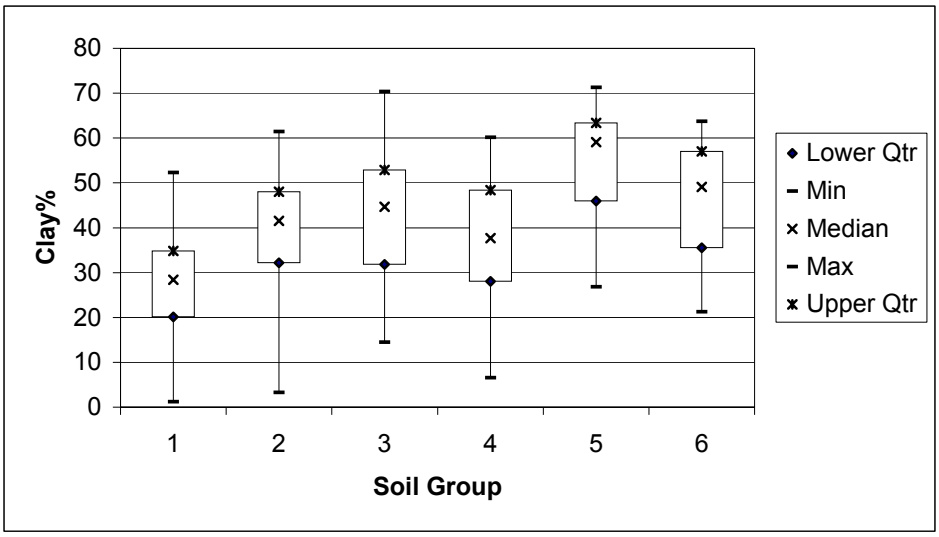

Figure 6.12 Clay Content of Horizon B1

Figure 6.12 is a box and whisker plot of clay content of Horizon B1. Horizon B1 has larger bands of clay content between upper and lower quartiles of soil groups compared to Horizon A. This suggests that clay content of Horizon B1 within soil groups is more variable compared to clay content of Horizon A. Clay percentages of Groups 2, 3 and 4 are not found significantly different when their means are compared in t-tests.

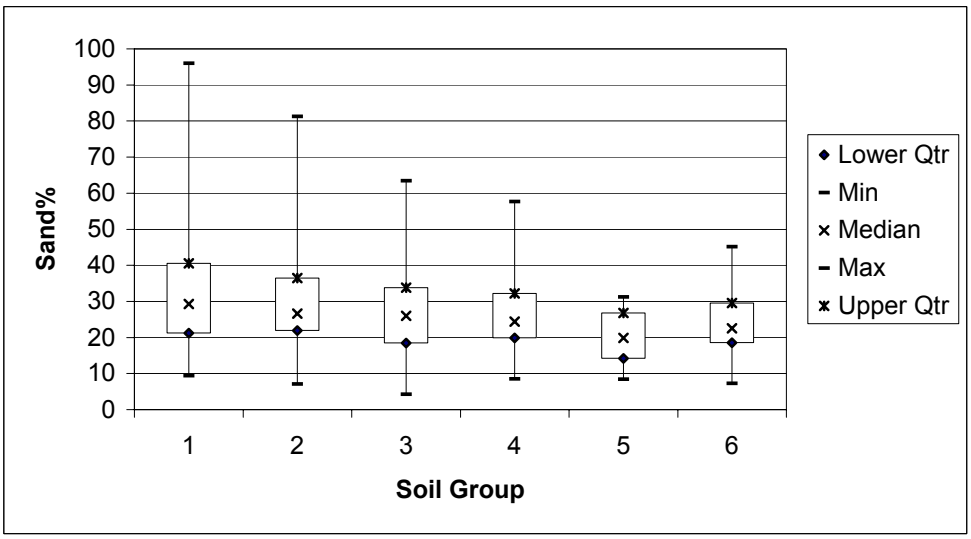

Figure 6.13 Sand Content of Horizon B1

Figure 6.13 is a box and whisker plot of sand content of Horizon B1. Except Group 6, median values show a decreasing trend with soil group. Although the sand percentage of each soil group is distributed over a large range, the bands between upper and lower quartiles are relatively narrow for most of soil groups.

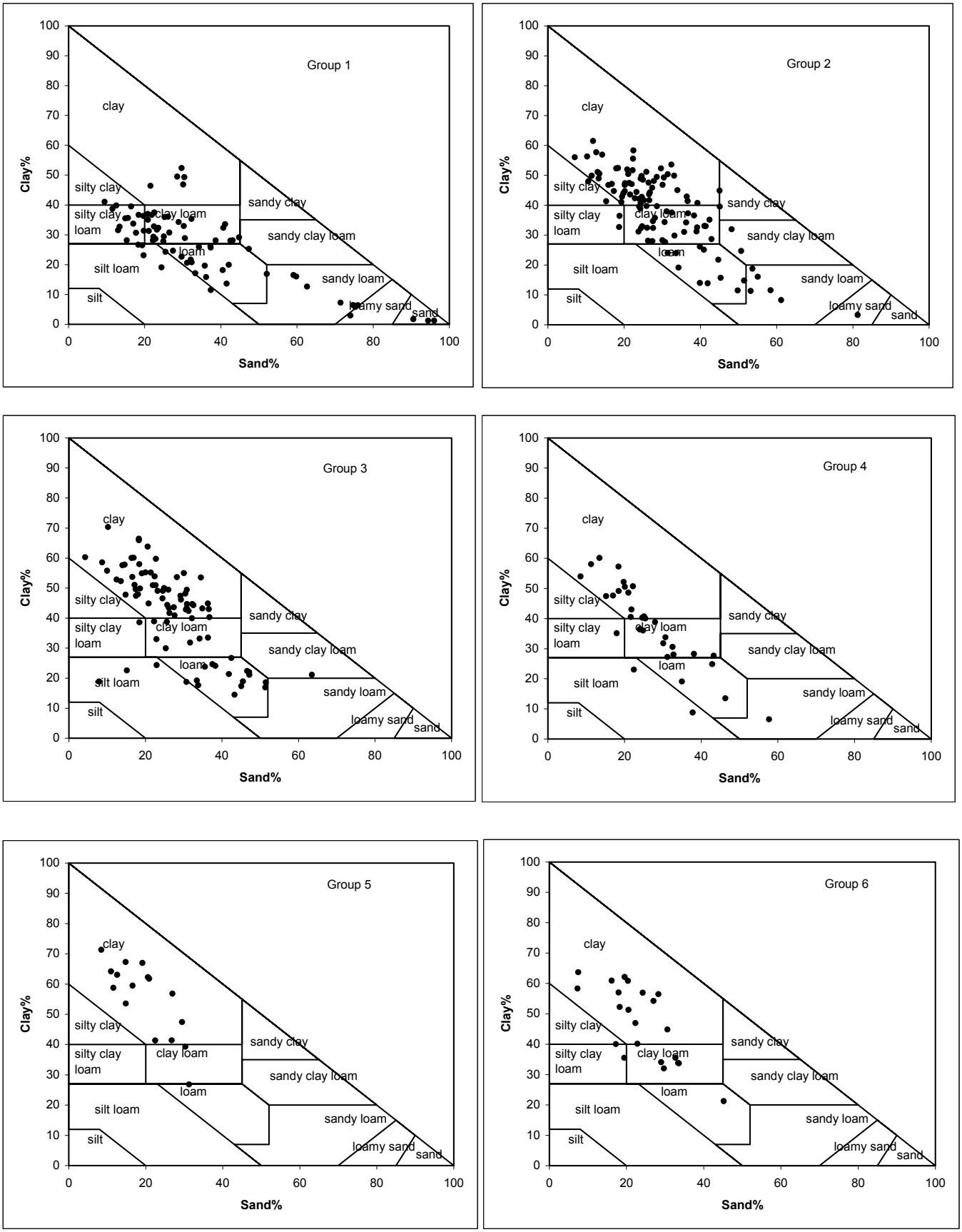

Figure 6.14 Particle Size Distribution of Soil Groups (Horizon B1)

Figure 6.14 shows particle size distributions of Horizon B1 of data from all sampling points in the SIR on the USDA soil texture triangle. For Groups 1 and 2, textures are concentrated mainly on sandy loam, loam, clay loam, silty clay loam and clay texture. For Groups 3 and 4, particles are concentrated on loam, clay loam and clay. For Groups 5 and 6, textures are concentrated on clay loam and clay. It shows that texture is slowly changing with soil group. Groups 5 and 6 are relatively well defined compared to other groups. Clay percentages of Groups 1 and 2, Groups 3 and 4, and Groups 5 and 6 are not significantly different from each other when their means are compared in t-tests.

Figure 6.15 shows the comparison of average clay content of Horizon B1 of soil groups between three irrigation districts (MV, GV, RO) of the SIR. Group 1 of MV district has much lower clay content compared to the other two districts because MV district's Group 1 soils are dominated by sandy soils such as Sandmount sand. It appears that soils of Groups 4, 5 and 6 in RO district have higher clay percentage compared to those in the GV and MV districts. Average clay content in Groups 2 and 3 is not much different among the three districts.

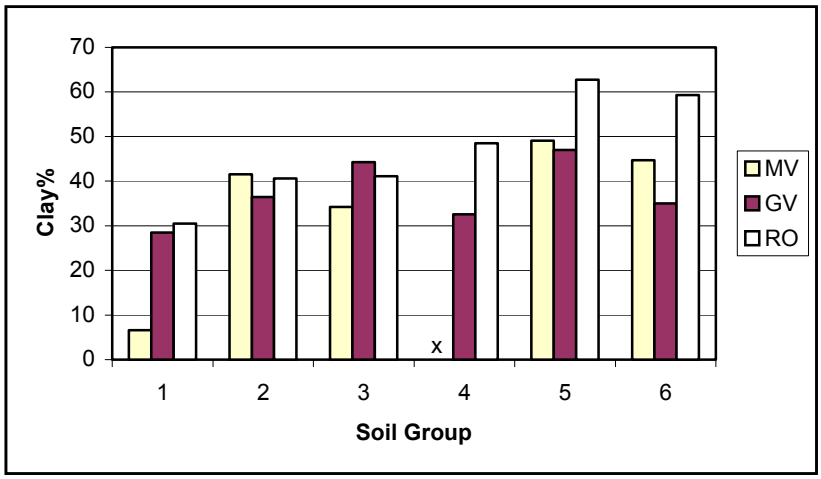

Figure 6.15 Clay Content of Horizon B1 in MV, GV and RO Districts

Table 6.9 lists measured clay content of Horizon B1 of 34 soil types. To understand the variability of clay content between and within soil types, the clay content of selected soil types is plotted in Figure 6.16. It appears that the variation in clay content within some soil types may be as much as that within their soil group. On the other hand, some soil types have narrow bands between upper and lower quartiles and are well defined. There is also a large variability of clay content between soil types, especially in Group 1. For example, Ss and Ssp soil types are significantly different from ESfsl and Nfsl in Group 1. Horizon B1 has larger bands between upper and lower quartiles of soil types compared to Horizon A. This suggests that Horizon B1 has larger within-soil-type variability compared to Horizon A.

Table 6.9 Clay Content in Horizon B1

Irrigation District	Soil Group	Soil Type	No. of Sampling Points	Clay (%)						
				Mean	Std.	Min.	Max.	Percentile		
								25	50	75
MV	1	Sandmount sand	4	2.6	2.5	1.2	6.4	1.2	1.5	4.1
	1	Sandmount sand phase	4	5.7	1.9	3.0	7.3	4.5	6.2	6.8
	1	Cobram sandy loam & Ss	2	16.3		12.6	19.9			
	2	Waaia loam	10	40.4	14.2	3.3	53.6	39.7	43.9	47.6
	2	Waaia loam phase	4	47.7	3.8	42.0	50.4	45.3	49.1	50.1
	2	Cobram loam	12	36.3	11.3	14.8	50.4	26.9	37.4	47.0
	2	Moira loam friable phase	10	46.5	9.4	31.2	58.3	37.5	49.4	52.3
	3	Moira loam	2	32.5		22.0	43.0			
	3	Naring loam	8	34.6	19.1	16.9	66.4	18.0	31.1	47.7
	5	Ulupna clay	2	49.1		26.8	71.3			
	6	Muckatah clay loam	6	43.8	12.0	33.9	60.9	35.5	37.8	57.0
	6	Boosey loam friable phase	4	42.5	15.1	21.3	57.0	33.1	45.9	52.0
	6	Boosey loam	2	51.8		51.3	52.3			
GV	1	East Shepparton fine sandy loam	14	28.5	7.9	15.8	46.4	25.3	28.1	33.0
	2	Ketamatite loam	4	20.9	11.3	11.6	37.3	13.8	17.4	28.0
	2	Shepparton fine sandy loam	54	37.6	11.2	11.5	57.7	31.0	39.6	44.9
	3	Lemnos loam friable phase	8	46.6	9.9	31.9	60.1	38.7	47.4	54.5
	3	Lemnos loam semi friable phase	4	45.3	3.5	40.9	49.4	42.8	45.4	47.8
	3	Lemnos loam	37	42.6	13.9	14.5	70.4	32.4	43.6	51.3
	3	Goulburn loam friable phase	4	54.1	4.8	48.2	59.8	50.9	54.3	57.3
	4	Goulburn loam	20	33.0	13.1	6.5	50.5	26.3	35.6	40.6
	4	Goulburn clay loam	4	30.7	4.1	27.3	36.5	27.8	29.4	33.5
	5	Congupna clay loam	6	47.0	7.8	39.3	58.8	41.4	44.5	53.6
	6	Congupna clay	4	35.0	3.6	32.0	40.2	32.9	33.9	37.1
RO	1	Nanneella fine sandy loam	54	30.5	9.0	11.5	52.3	24.6	31.0	35.9
	2	Timmering loam	18	40.6	14.6	8.2	61.5	34.3	43.4	50.5
	3	Wanalta loam	22	41.1	15.5	17.7	60.1	22.6	47.9	53.7
	4	Wana loam	2	59.1		58.1	60.1			
	4	Koyuga clay loam	4	51.9	4.1	47.5	57.3	49.1	51.5	54.7
	4	Koga clay loam	4	39.7	12.8	23.1	54.0	31.0	40.9	48.5
	5	Rochester clay	2	59.5		56.8	63.7			
	5	Alta clay loam	6	63.8	3.0	59.5	67.3	61.8	63.6	67.0
	6	Wallenjoe clay	2	61.0		58.3	63.7			
	6	Carag clay	4	58.4	3.7	54.2	62.1	55.3	58.7	61.5

Figure 6.17 shows within-paddock-variability of clay content measured on seven paddocks mapped with a uniform soil type and one mixed paddock mapped with four soil types. It appears that Horizon B1 has larger within-paddock-variability than Horizon A. Comparison of Figures 6.16 and 6.17 shows that a single paddock of a uniformly mapped soil type covers a large part of the variability in clay content within the soil type between lower and upper quartiles. Within-paddock-variability of clay content of some uniformly mapped soil types such as Gl is comparable to that of a mixed paddock containing four different soil types.

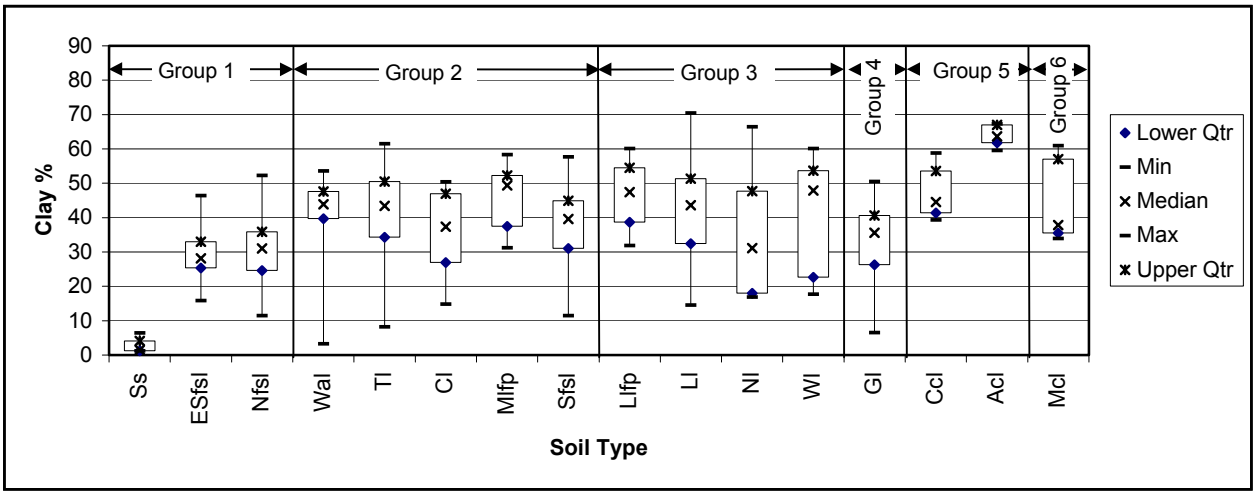

Figure 6.16 Clay Content of Horizon B1 of Selected Soil Types

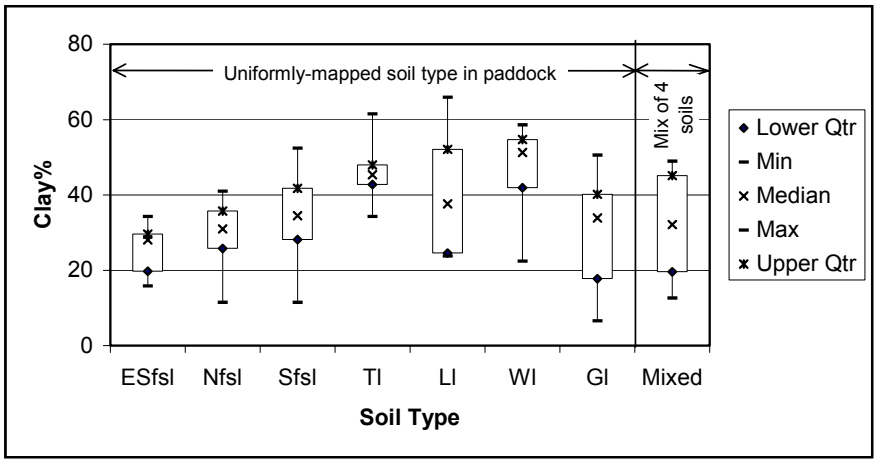

Figure 6.17 Clay Content of Horizon B1 in Paddocks of Selected Soil Type

6.2.4 Summary

The following can be concluded from the results of the texture analysis:

- Clay content of Horizon A shows an increasing trend from Group 1 to 5.
- Soil texture of Horizon B1 has larger within-group-variability of clay content than that of Horizon A.
- At a paddock scale, variability of clay content can be quite high. A paddock of selected soil type can cover a large part of within-soil-type variability between upper and lower quartiles.
- Groups 1 and 2, Groups 3 and 4, and Groups 5 and 6 are statistically not different from each other based on soil texture.
- Soil texture of the Ss and Ssp soil types of Horizon A of Group 1 is clearly different from other soils of Group 1.