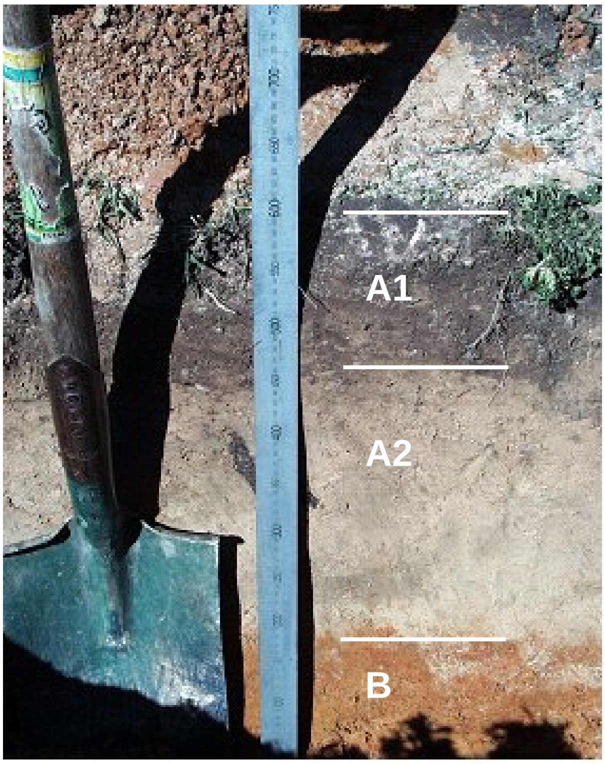
Collecting Soil Inputs for GRAZPLAN Decision Support Tools



Richard Simpson, Phillip Graham, David Marshall, Adam Stefanski, Libby Salmon and John Donnelly

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Methods for the sampling and analysis of the physical properties of soil profiles required for grazing systems simulation.

Collection of soil profile data can be time consuming and expensive but the data are essential inputs for grazing system simulations. The simulations, in turn, provide us with unprecedented capability to explore grazing systems management. Soils are often not uniform and a practical method is needed for sampling paddocks to obtain representative soil samples suitable for measurement of the hydraulic properties (drained upper limit (field capacity), drained lower limit (wilting point) and saturated hydraulic conductivity) and physical properties (bulk density, texture and depth) of each soil profile.

A guiding principle for soil sampling is to consider how GrassGro will use the information, and the depth to which roots are found in the soil profile.

What purpose does a soil profile serve in a GrassGro simulation?

In relatively simple terms GrassGro uses the soil profile as a medium that:

(a) ***provides nutrients for plant growth*****:**
This is simulated generically using the soil fertility scalar [scale 0.5: extremely poor-1.0 (maximum)],

(b) ***stores moisture*****:**
This is determined by the depth and water-holding characteristics of the soil profile. GrassGro recognises two soil horizons (“A” = topsoil, with a depth that is measured at each site; “B” = subsoil, with a depth that extends from the base of the A-horizon to the depth of the root system). Plant-available water is the amount that is held in the soil between its drained upper limit (DUL) or field capacity, and the drained lower limit (DLL) or wilting point. The rate at which water moves through and drains from the soil profile, or is shed as runoff is determined by the rate at which rain falls, the current water content of the soil profile, the water content at saturation (Sat) and the saturated hydraulic conductivity (Ksat) of the soil layers,

(c) ***may restrict plant growth*****:**
Hard soil slows root growth (this is predicted by a relationship between root growth and soil bulk density), and chemical toxicities (e.g. salinity, aluminium toxicity in very acid soil) may also restrict plant production (this is handled generically using the fertility scalar). Aspects of root growth and the depth of “effective” roots in soil are poorly understood. Soil hardness may not be uniform and root growth in biopores can in some instances be a dominant influence on plant performance. Where there is sufficient evidence that root growth is not predicted well, GrassGro also allows the user to specify the depth to which roots grow based on information gathered from the pasture that is being simulated.

What is the soil profile information to be used for?

GrassGro simulates production at a single point in a landscape but it is generally more useful if a simulation reflects the production that is possible across large parts of a farm or district landscape. For this reason, it is desirable that the soil profile used for a simulation is a reasonable representation of the soil underpinning a broad farm landscape. Soil can vary even over small distances, so it is necessary to gather information about the variation in soil properties across the paddock or landscape of interest and to select sites for collection of soil samples. Sampling and measurement of soil physical and hydraulic properties is expensive and samples are, therefore, usually taken from a limited number of “representative” sites. The steps presently taken when selecting representative sites and collecting soil information from them are detailed below.

(1) Identify landscape and soil classes
Potential differences in soil type may be identified initially by partitioning a farm landscape on the basis of its land classes using physical features such as aspect, slope, changes in soil

texture and colour, and differences in the natural vegetation. It is important to remember that gross differences in soil colour and slope may not always indicate substantial differences in soil hydraulic properties, which are the key features of the soil that must be described for a simulation.

(2) Scoping runs and choice of primary sites for soil profile samples
The next step is to survey variations in the soil profile across the area of interest within each class of land. It is usually only cost-effective to take a small number of soil samples so the samples should be reasonably representative of the larger area. The survey may occur on a grid or along a transect. The aim is to identify the extremes of soil profile variability and to determine whether a representative soil profile can be ascribed. A mechanically-driven soil corer (600 x 30 mm diam.) is required for the task (Fig. 1)

In the initial survey, the following features of the soil profile are noted:

1. field soil textures (minimum description: A1, A2 and B horizons),
2. horizon depths,
3. soil colour and, for instance, occurrence of bleached layers which provide qualitative indications about drainage characteristics of the soil horizons, etc.,
4. occurrence of roots with depth,
5. existence of large biopores that may preferentially influence root distribution and drainage (eg. old root channels through impermeable clay layers),
6. occurrence of gravel and rock.

An example of a preliminary survey showing soil horizon depths and soil colour distribution is shown in Figure 2. This particular example illustrates how slope of a paddock may sometimes have no bearing on soil layer depths or occurrence of waterlogging (bleached soil).

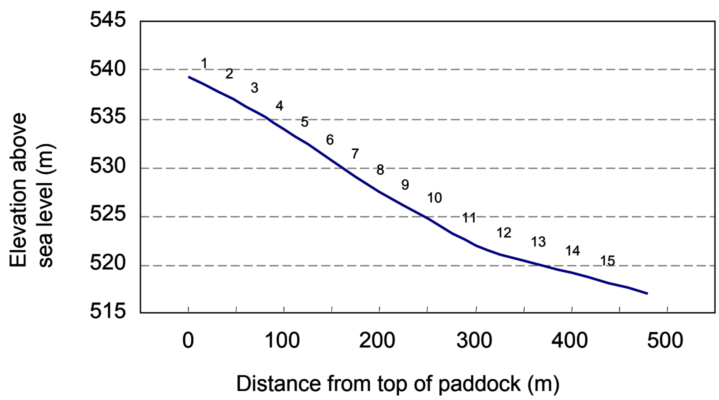
For typical GrassGro simulations we use a minimum of three sites for collection of soil profile samples to limit the costs of sampling and measurement. This is a pragmatic compromise, however, a sample size of three is also reported to be adequate for most of the intended measurements (McKenzie and Cresswell 2002). It is usual practice to use the information gathered in the preliminary survey to choose three sites that represent soil profiles “typical” of the main area being simulated.

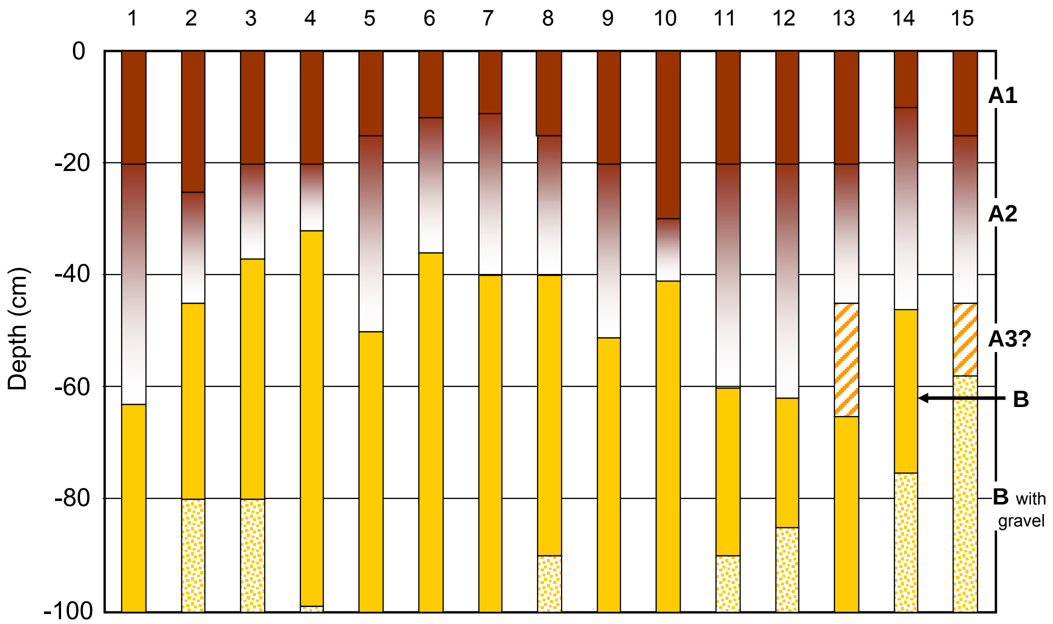
Soil across some paddocks can be very variable and is of particular concern if wide variations in soil texture occur. The first step is to review whether the area being sampled has been identified correctly as a single land class. In highly variable paddocks, sampling divergent sites, as opposed to three “representative” sites, may be essential. Simulations are conducted subsequently using the range of soil profiles encountered.

(3) Taking soil samples for measurement of hydraulic properties
Timing: the soil samples can only be taken as intact cores when soil is wet and soft. This usually means there is a short window of opportunity for sampling in autumn and again in spring. Soft soil allows coring devices to be driven into the soil strata without distorting the core. Samples also cannot be taken when the soil is too wet (i.e. approaching a water-logged condition) as soil in the coring device tends to slump and distort, or may flow out of the coring devise. Distortion of the soil structure affects the air-filled spaces in a soil profile and will lead to incorrect estimates of water holding capacity and hydraulic conductivity. Root depth observations are of most use when done at sampling times in late spring.

Where to sample within the soil profile: the siting of soil samples within a soil profile is determined by pragmatic consideration of the information required for a GrassGro simulation. GrassGro only recognizes two distinct soil horizons. Depth of the A horizon in GrassGro is

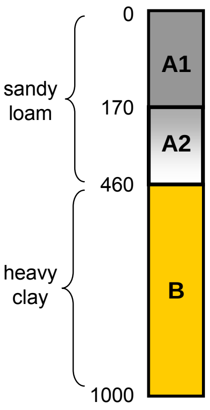
Figure 1. Soil core collection and examination during an initial survey of soil profiles across a paddock.





Transect through fertilised pasture, Bookham Grazing Demonstration, "Kia-Ora"

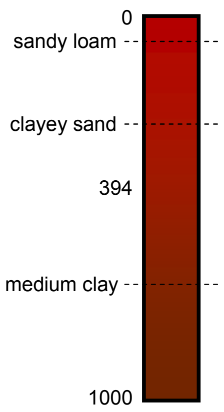
Figure 2. Slope, depth and colour changes observed in soil profiles sampled along a transect in the fertilised paddock in the Bookham Grazing Demonstration at "Kia-Ora".



Duplex soil (chromosol); "Kia-Ora", Bookham

Soil horizon	Depth (mm)	Bulk density	DUL (% vol)	DLL (% vol)	Ksat (mm/h)	GrassGro inputs DUL (% vol)	GrassGro inputs DLL (% vol)	GrassGro inputs Ksat (mm/h)
A1	170	1.36	34.4	9.6	62	26.4 #	6.7	62
A2	460	-	23.6	5.8	-			
B	1000+	1.7	32.8	27.8	0.011	32.8	27.8	0.011

DUL(A horizon) = (34.4*170/460) + (23.6*290/460)



Structured soil (dermosol); "Canalong", Beremangra

Soil horizon	Depth (mm)	Bulk density	DUL (% vol)	DLL (% vol)	Ksat (mm/h)	GrassGro inputs DUL (% vol)	GrassGro inputs DLL (% vol)	GrassGro inputs Ksat (mm/h)
A (< 293 mm)	394*	1.43	23.3	14.9	212#	23.1 ♣	13.7	212
A (394 mm)		1.58	22.6	10.4	513			
B	1000	1.54	35.0	24.0	25	35.0	24.0	25

* boundary not distinct, but is an average value assigned on basis of increase in clay content.
# lowest K_{sat} value is used because this acts as a "throttle" for water movement in the layer.
♣ DUL(A horizon) = (23.3*293/394) + (22.6*101/394)

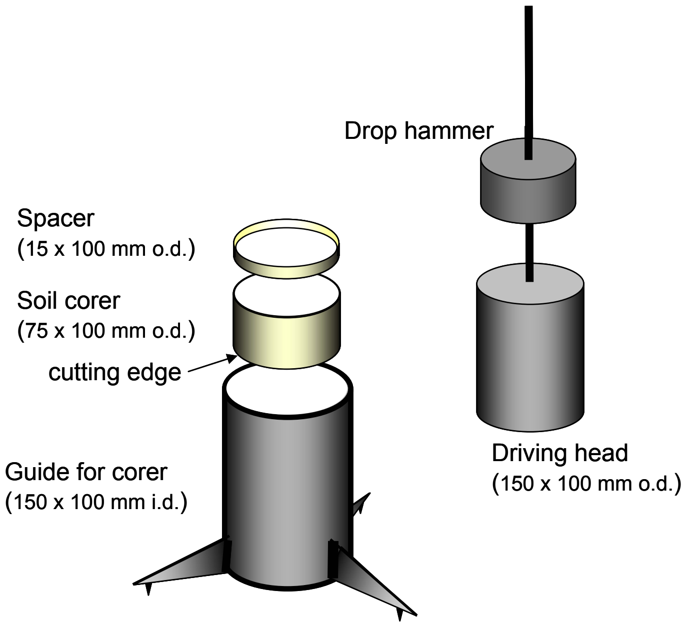
Figure 3. Physical properties of two soil profiles and treatment of the data for use in GrassGro simulations.

set to reflect the overall depth of the A horizon in the paddock being simulated. In duplex soils, depth of the A horizon is easily identified and is the depth at which a significant change occurs in soil texture. It is not necessarily the depth at which soil colour changes.

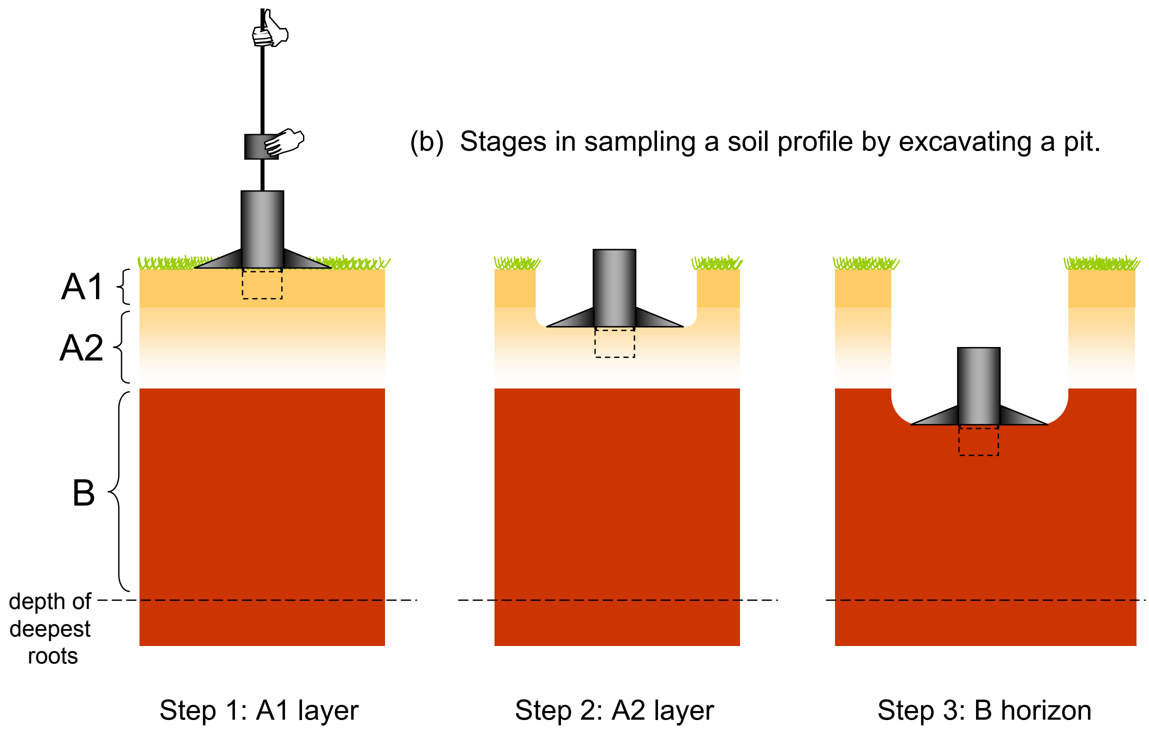
Within the A horizon of many soils, colour and less dramatic soil texture changes also occur. These features of the A horizon are used to guide soil sampling. Recognition of A1 and A2 layers is required and it is necessary to record their depth and to sample them separately. A weighted average (based on depth) of the hydraulic properties of these layers is used to describe the A horizon for use in GrassGro (see worked example in Figure 3). Note: Ksat is not treated this way (see Fig. 3).

Although GrassGro considers the depth of the B horizon to be the depth to which the deepest roots have grown, the user is required to specify actual soil depth from field observations because this sets the maximum depth to which roots may grow. Occasionally soil depth is constrained by a bedrock layer and if sufficiently shallow this will also constrain root growth.

Sampling the B horizon is more problematic because it is difficult to access and is often comprised of harder soil. Soil cores from the scoping run are examined to determine the depth at which a soil sample should be taken. The aim is to take reasonably representative



(a) Soil coring device (after McIntyre 1974)



(b) Stages in sampling a soil profile by excavating a pit.

Figure 4. (a) Equipment, and (b) method for soil core removal by digging shallow pits at representative locations in a grassland landscape.

Figure 5. (a) Preparations for collecting a soil core from an A1 horizon, and (b) distinct A1, A2 and B horizons in a duplex soil at "Blackburn", north of Yass. Note: colour differences are a useful guide for sampling soil but are not as important as changes in soil texture.

samples. The main uses of B horizon information in a simulation are to define the amount of water at depth that roots can access, and to regulate the rate that water enters, or drains from the soil profile. These considerations should be used to guide where soil samples are to be taken. Most commonly B horizon samples are taken from a pit that has been created as a consequence of sampling the A horizon. It is important to dig into the upper face of the B horizon at least to a depth where all vestiges of A horizon material have been removed. In soils that do not have a distinct A and B horizon, it is still necessary to sample A1 and A2 layers and to make a judgement about where to site the "B" sample. Even in deep sands the bulk density and consequently the hydraulic properties of soil may vary with depth.

Method of soil core removal: Three pits (replicates) will be dug in most paddocks at sites representative of the soil profile of the area to be simulated. Within each pit, three soil samples are usually taken (i.e. A1, A2 and B horizon samples; Fig.s 4 and 5). The soil corer is lightly oiled by wiping it with a rag dipped in household vegetable oil and is driven carefully into the soil until the spacer ring is flush with the soil surface. The corer is then excavated with care using a small hand trowel, spatular or knife and is finally undercut with a knife to ensure the soil core is not distorted and exceeds the volume of the sleeve. The soil core will be carefully trimmed to size in the laboratory to give a flat face for good contact when placed on a ceramic pressure plate and for accurate estimation of bulk density.

(4) Transfer of samples from paddock to laboratory (*storage issues*)
Each soil corer containing a soil core is placed in a stout plastic bag, wrapped and held firm with a rubber band. This has the dual purpose of protecting the soil core and maintaining its moisture content. Cores are kept as cool as possible (transported in an Esky) and if held before analysis, are kept at 4^{o}C. The aim being to reduce the possibility of earthworm or other soil macrofauna activity. The drainage and water holding capacity of cores will be substantially modified by such activity should it occur.

Measurement of the hydraulic and physical properties of soil

Processing of soil cores for measurement of their hydraulic and physical properties requires specialist skills and equipment, and is most often contracted to a suitably equipped soil laboratory. The measurements can be labour intensive and are expensive.

The methods we have used for GrassGro analyses are:
DUL: GrassGro uses the "draining soil water characteristic" of the soil sample and the parameters are prescribed as the volume fraction of water in the soil (m^3/m^3). A ceramic suction plate method (Method 504.01, Cresswell 2002) at constant temperature (~20^{o}C) is used for DUL determination. The soil core is left in the metal corer, the ends are trimmed flush with a sharp knife and the core is placed on a ceramic plate or blotting paper and wetted with de-aerated 0.01M $CaCl_2$ first by capillarity, followed by incremental immersion over a few days until saturated.

(*Note: water content at saturation (Sat) may be determined at this point by immersion to within a few millimetres of the top of the core. However, this information is not required for GrassGro which calculates Sat from the soil bulk density: Sat = 0.93*(1-BD/2.65*).

The core is then placed on a ceramic suction plate and DUL is calculated from the water content achieved after suction is applied at -9.8 kPa (-1.0 m water at 20^{o}C).

DLL: A ceramic pressure plate is used to determine the DLL from the water content achieved when pressure at 1500 kPa (equivalent to a suction tension of -150 m water) is applied to soil samples or cores sitting on the ceramic plate (Method 504.02; Cresswell 2002).

Ksat: Method 510.01 (McKenzie et al. 2002a) in which a plastic collar is attached to the base of the metal soil coring sleeve containing the soil core, the ends of which have been "picked" to eliminate smeared surfaces. The soil core is inverted and submerged in a constant head tank of 0.01M $CaCl_2$ and left to equilibrate overnight. After equilibration, solution is removed from within the plastic collar so that a constant head is maintained and the rate of flow through the soil core in the natural direction of flow is recorded.

Bulk density: Intact core method 503.01 (Cresswell and Hamilton 2002) in which bulk density of the soil core, trimmed to exactly flush with the ends of the corer sleeve with a knife, is calculated from the volume of the sleeve and the oven-dry (105°C) weight of the soil. When conducted as the last step in a sequential series of measurements it is important to retain and weigh soil removed in "pickings", and/or to measure the volume of any indentations by recording the volume of a fine sand applied to fill the indentations.

Full details of these methods, equipment required, calculations and trouble-shooting are found in McKenzie et al. (2002b).

Acknowledgements

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