SOIL WINDOWS – UNRAVELLING SOILS IN THE LANDSCAPE AT THE FARM SCALE

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Abstract

S-map is the new national soils database that aims to provide a seamless digital 1:50,000 scale soil map coverage for New Zealand. Mapping for S-map is underway across the Waikato Region. A concurrent project, Waikato Soil Windows, has been initiated with the aim of (1) formalising soil–landscape relationships developed and used by pedologists undertaking S-map soil mapping, and (2) increasing the accessibility and uptake of soil information by land managers for farm management decision making. This paper describes how S-map information can be used to help achieve these goals. During recent S-map soil surveys in the Waipa and Upper Waikato catchments, detailed soil–landscape models have been, or are currently being, developed. Pedologists develop soil–landscape models while undertaking soil surveys to help them understand the relationships that control and explain the soil pattern within a land region. However, the models are not always explicitly communicated to the end user or other pedologists. Capturing and articulating these relationships will document the ideas used to determine soils in the landscape and will assist with further soil mapping in the future. There is growing interest in making use of the soil information contained in S-map for farm management decision making. At a scale of 1:50,000, the resolution of the spatial information in S-map may be too coarse for farm- or paddock-scale management without additional, detailed soil data (sibling data) and an understanding of the soil-landscape relationships. A well-presented and communicated soil–landscape model can be thought of as a ‘window’ that provides land managers with an insight into the soil pattern within a particular area. Moreover, these models (or ‘soil windows’) could facilitate the development of farm-scale soil maps by suitable skilled professionals that could then be linked to sibling data in S-map. The soil information held in the sibling database, captured and linked to the online 1:50,000 soil polygons during the S-map survey process can be used at multiple scales. Greater value could potentially be derived from the sibling data if it were made more accessible to land managers. These data have multiple uses in the management of nutrients, water, effluent, cultivation, and grazing.

Introduction

Provision of information on the nature and distribution soils and soil properties at appropriate resolutions will be fundamental to the successful design and implementation of farm management practices to reduce the loss of nutrients and sediment from land to waterways. The fundamental soil layer (FSL), derived from the Land Resource Inventory, is the most detailed soil map with complete national coverage presently available. However, the FSL is based on dated and coarse resolution soil maps (General Survey of the Soils of New Zealand – DSIR 1954, 1968) in many parts of the country. Regional council-funded soil survey work to provide soil spatial information of better resolution and more consistent quality is currently underway in some regions using the S-map approach.

S-map is the new soil spatial database that aims to provide a seamless digital 1:50,000 scale (or better) soil map coverage for New Zealand. Mapping in the Waikato region has been progressing over the last 4 years with approximately 60% of the region's area (2.4 million ha) covered by S-map at present. The field checking, re-interpretation, and incorporation of suitable existing (legacy) soil maps and their associated map unit data into the S-map database has aided progress. Of the approximately 1.4 million ha of the Waikato now covered by S-map, about 1.1 million ha was achieved using legacy data, with less than 300,000 ha covered by new mapping specifically for the purpose of S-map to date. However, new field soil surveys will be required to complete the S-map coverage for the remainder of the Waikato region (about 1 million ha).

The prospect of a substantial programme of new soil mapping presents both opportunity and need. The opportunity rests in the chance to intentionally capture and make explicit the detailed knowledge and understanding of the soil–landscape relationships and resulting soil patterns the pedologist tacitly accumulates and synthesises in the course of undertaking a soil survey. A detailed and well-communicated record of this information would be extremely useful to the pedologist undertaking further soil mapping in similar unmapped landscapes or at more detailed resolution than that of S-map at present (1:50,000). In less detailed form, others could also benefit from the communication of this information through gaining a better understanding of the soils and soil patterns within the region. The need exists in the form of how best to 'bridge the gap' between soil information provided at a resolution of 1:50,000 by S-map and farmer's and land manager's need for soil information to guide land management decision-making at the farm scale. The idea for the 'Soil Windows' project emerged in response to this opportunity and need.

The soil windows concept involves gaining an understanding of the soil pattern within a small representative area of land (i.e. a 'window') through the development of soil-landscape models and their constituent soil-landscape relationships which can then be applied to understand the soil pattern across a much larger area of the surrounding land. While the concept is not new, using this methodology to interpret the soil-landscape in S-map soil units has not been proposed before. In order to fully explain the soil pattern within a particular area of interest, multiple soil–landscape models may need to be developed. For instance, a general soil–landscape model that defines the broader soil and landscape patterns and how these relate to the soil parent materials may be necessary. Such a model has been previously developed for the Hamilton basin and is illustrated below (Figure 1). This is a good example of how a fairly detailed conceptual model can be presented using a stylised diagram. This general soil–landscape model for the Hamilton Basin was initially developed by Grange et al. (1939), while Bruce (1979) illustrated the model as a stylised block diagram. Singleton (1991) developed this concept further in his publication on soils of Ruakura where he demonstrated how a small area (Ruakura research farm) can be used to illustrate soil patterns that are apparent over a much larger area of the Waikato. In these publications, various components of the landscape are defined with respect to the soil pattern. Key to understanding the soil–landscape relationships are descriptions of landscape processes and the soil materials involved in these processes. It is also very important that the soil types used in the development of the soil–landscape models are well defined so that they are meaningful to, and can be readily identified in the landscape by, users of the models.

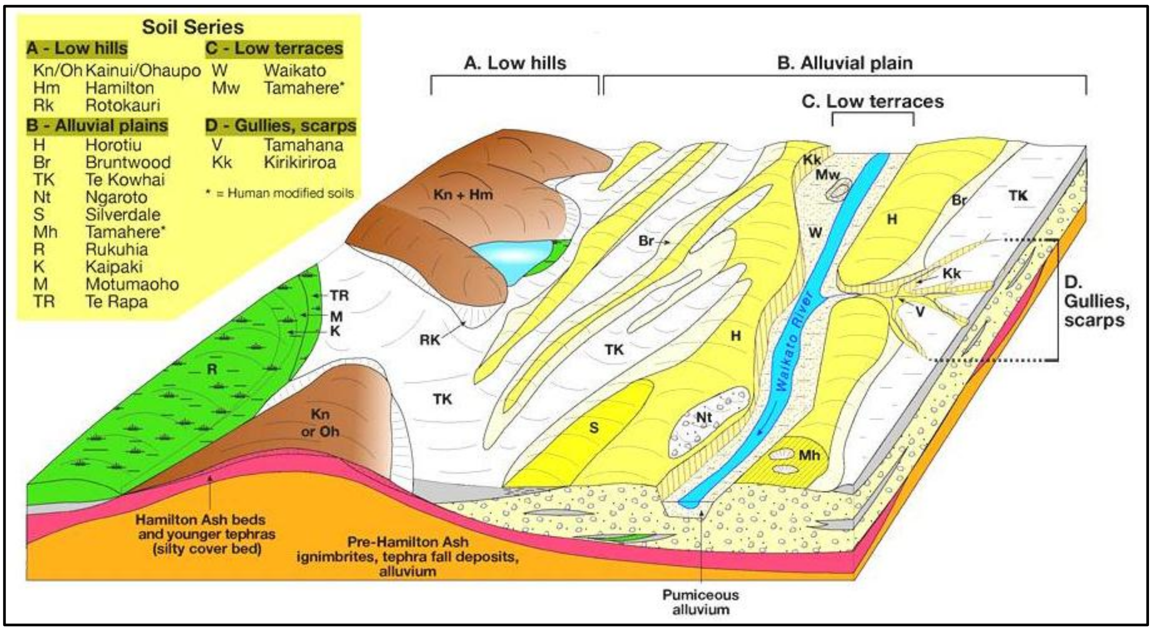

Figure 1: Soil-landscape model developed to illustrate the general pattern of soils to the landscape and parent materials of the Hamilton Basin (courtesy of David Lowe).

The objectives of the Waikato Soil Windows project are to (1) formalise soil–landscape relationships developed and used by pedologists undertaking S-map soil mapping, and (2) increase the accessibility and uptake of soil information by land managers for farm management decision making. This paper outlines the development of the project to date and highlights the potential linkages between the S-map database and the use of the soil-landscape models developed at the farm scale.

Developing a Soil Windows approach

Development of the Soil Windows concept and approach began with two workshops. The first workshop brought farmers and farm consultants together with WRC staff and LCR pedologists to discuss how soil information could be used, its value to farming, and how it might be made more accessible to the farming industry. The second workshop involved soil experts from LCR, WRC, and the University of Waikato to discuss how Soil Windows might be developed. A review of soil survey publications relevant to the Waikato was also undertaken to investigate what types of soil landscape models already existed that could be adapted for use in Soil Windows. Initial field-based work was undertaken in the south Waikato area (near Tokoroa) to improve the concept and approach further through the development of soil–landscape models that describe soil patterns at the farm scale and in response to broader-scale gradients in parent material and rainfall. This work followed on from the soil mapping work undertaken in the area. Soil mapping is currently underway in the Waipa catchment and so the next set of windows to be developed to further refine and establish the approach will be in the Waipa catchment.

Understanding Soils in the Landscape

Soil survey work follows a general process: (i) the pedologist gathers relevant survey material such as previous soil information for this or similar regions, geological and geographical information and air or satellite imagery; (ii) a reconnaissance of the proposed survey area will then put this information into context and help define the soil landscapes – this preliminary exercise will help inform the pedologist of the general soil pattern and develop a conceptual soil-landscape model; (iii) as the survey progresses, the model is developed and tested, which is what helps the pedologist understand and predict soils across the landscape. Broadly speaking, there are two areas to which the soil windows concept could be applied. First, the pedologist can convey how the soil map has been developed using soil windows. In the process of developing soil windows, the pedologist translates the conceptual soil–landscape models, developed tacitly as part of the soil survey process, into actual soil-landscape models through the use of schematic diagrams, photographs, tables, and soil–landscape descriptions based on detailed observations across representative soil–landscape units (such as catenas) at the farm scale. Soil windows could be particularly useful for enabling other pedologists to understand the thinking behind a soil map to extend the map or improve its resolution in the future. This first application of soil windows is primarily for use by other pedologists and may be quite technical in the detail. Second, soil windows could be used to convey soil information to non-experts (e.g. farmers or land managers) so that the information can be more widely disseminated and utilised. The primary aim is to enable end users to assign soil types to a defined landscape pattern at the farm scale. This application would require simplification of many of the more technical aspects to enable understanding by a wider audience and could be thought of as providing a 'road map' rather than a technical manual. Both approaches to soil windows will follow a similar process of development, with the presentation of information the main difference between applications.

Soil Windows in the South Waikato

In 2011, mapping for S-map was initiated in the South Waikato area east of the Waikato River between Putaruru and Broadlands (NE of Taupo) to 'fill' a hole in the S-map coverage of the central North Island. Two legacy surveys were used as a starting point but were not of sufficient quality to be included without significant field work. Approximately 50,000 ha (Tokoroa-Putaruru area) of the area to be mapped had no suitable map as a starting point.

An area of approximately 50,000 ha was chosen in the South Waikato (Figure 2) to develop the first soil windows. This area was surveyed the previous year for S-map at 1:50,000 scale and conceptual soil–landscape models were developed during this mapping. The landscape was broken into easy rolling to flat downlands and steeper hill country and upland. There are also two broad soil parent material types in the area – young Taupo Pumice (c. 232 AD eruption) and older weathered composite tephras. It is proposed to illustrate the landscape/parent material pattern in a stylised block diagram similar to Figure 1 to show how these important features sit within the South Waikato landscape. Three farms and three roadside transects were chosen, and detailed observations were made to determine the soil–landscape patterns that could explain the soil pattern to quite a detailed scale (suitable for farm-scale mapping). These six detailed mapping areas or windows (Figure 2) formed the basis for the two main land-scape models – a Pumice model and an Allophanic model, which together defined the soil-landscape for the intensive farming area within the South Waikato. Steeplands were not specifically included as the focus for this case study was on areas under intensive pastoral land use – a separate steepland model could be developed that would be more suitable for forestry in the area.

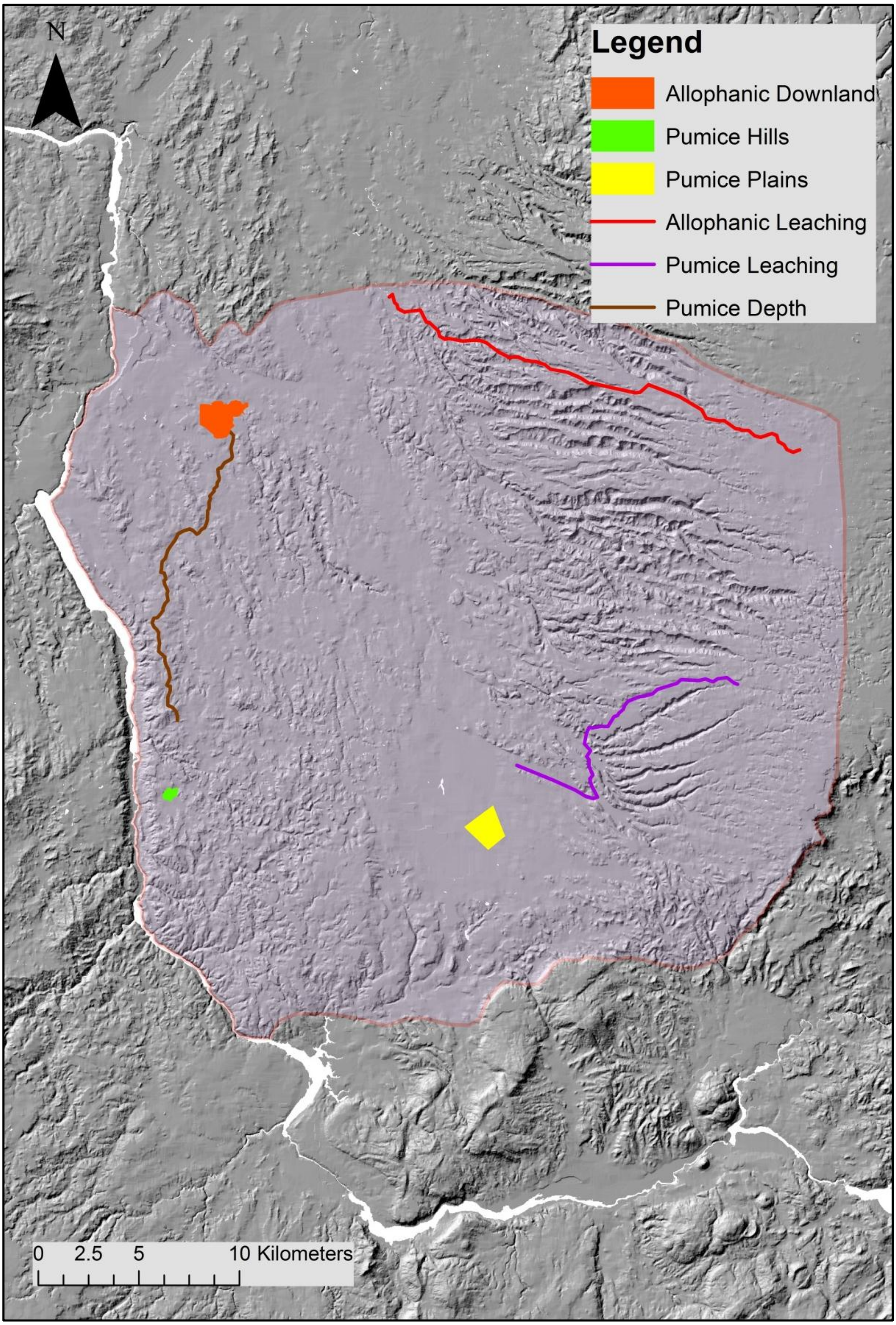

Figure 2: South Waikato area showing where detailed mapping was carried in the development of Soil Windows.

One farm that included all the important soils found in the Allophanic landscape was selected to represent the Allophanic downlands. As quite a different pattern was observed between rolling hill country and flat plains in-filled by deep pumice flows, two farms (one representing the Pumice Hills, the other representing the Pumice Plains) were required to encompass all the soils found in the Pumice landscape. Areas were then selected within these farms for detailed soil mapping. In the case of the Allophanic downlands, the whole farm was mapped. Three roadside transects were used to illustrate how certain soil features change gradually with distance (i.e. a gradient). For example, a 15-km transect in the direction of Lake Taupo showed how pumice depth increased closer to source (i.e. the Pumice Depth transect). Two other roadside transects (the Allophanic Leaching and Pumice Leaching transects) were used to illustrate how Pumice or Allophanic soils transition to Podzols across an elevation/rainfall (climate) gradient.

The Allophanic downland was sub-divided into seven simplified components (Figure 3). For the purposes of the Waikato Soil Windows project, a definitive landform hierarchy was not developed – Lynn and Basher (1994) discuss using a hierarchical landform analysis in soil landscape models to break the landscape into units within units: *"repetitive land characteristics may be identified and classified within a hierarchy of units at various scales"*. This may be useful to scale up windows to larger landscape models but a simplified system has been adopted that applies to a relatively small area and subdivides the landscape into more intuitive units for that particular landscape and also relates to specific soil mapping units. Subdividing the landscape into simple, easy to understand, local units might help convey meaning to a broader audience, but may be less suitable for more specific purposes of relating multiple components across a whole region such as the Waikato. However, these units could be correlated to more definitive geomorphological units in future.

The land components of the Allophanic downland window for the South Waikato are:

- Stream terraces with young alluvium (post AD 232 eruption).
- Old terraces higher in the landscape (generally on post 26 ka alluvium).
- Gully systems that cut through these terraces and connect streams to low hills
- Easy rolling hills
- Strongly rolling hills
- Hard ignimbrite hill slopes (ignimbrite is not soil forming)
- Soft ignimbrite hill slopes (ignimbrite is soil forming)

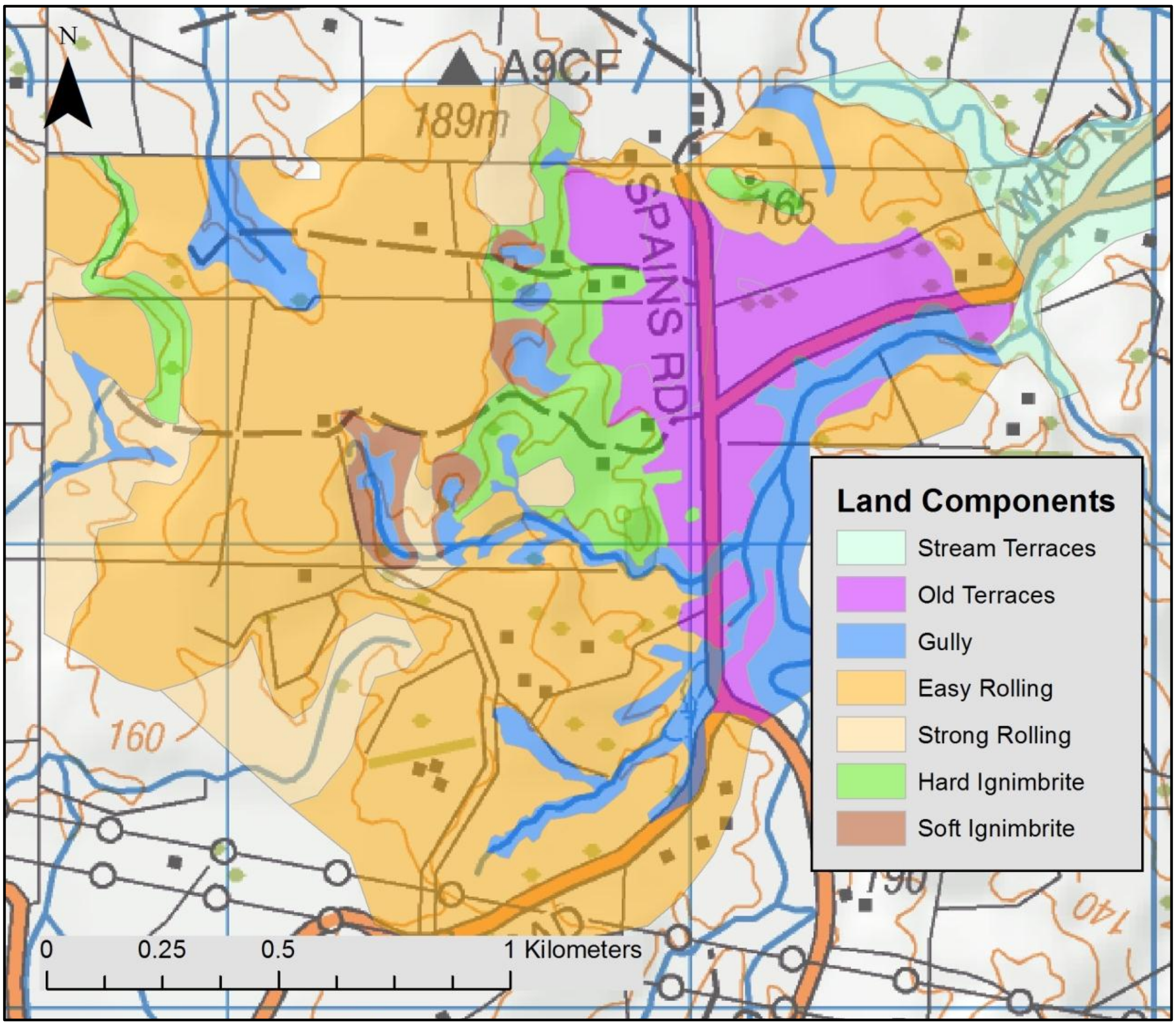

Figure 3: Land components applied to a South Waikato farm (Spains Road) in development of Allophanic downland window.

A set of soils was likely to be associated with each land component (Table 1). For example, on the easy rolling hills the soil pattern was very simple, with almost exclusively one soil described. The old terraces, however, had a more complex pattern depending on factors such as texture, drainage, and landscape position within this component. To identify the correct soil within this land component soil profile information would be required. These soils transition from well-drained Allophanic Soils through imperfectly drained Brown/Allophanic Soils to poorly drained Gley Soils, and are easily identified in the field using profile colours and mottles, for example. The soft ignimbrite hill slopes component also contained different soils (Allophanic and Brown) that were not easy to distinguish without some analysis of the soil (i.e. no discernible landscape expression of the pattern or obvious profile features). These three land components illustrate that there are differences in the Allophanic landscape in terms of the complexity of soil pattern, and also differences in the ease of distinguishing between different soil types on the basis of observable landscape/profile features. While it may not be easy for a non-expert to get the correct soil classifications for all the different land components on a farm, a windows approach does allow interrogation of the landscape in order to build a better understanding of the soil pattern. Where certain soil types within a land component cannot be easily distinguished spatially, it is still possible to get soil information from the S-map database on the range of potential soils and soil properties, provided the land component can be identified. In light of the information from S-map, a decision can be made as to whether or not differences between possible soil types are important or not for the specific needs of the user.

The intensive mapping carried out to illustrate the soil pattern of the Spains Road window during the development of the Allophanic downland model identified ten unique S-map soil siblings from five NZSC Soil Orders that could be mapped at farm scale (approximately 1:5,000). These, and a few other soils not mapped at Spains Road, could be listed as the most probable soils occurring in the Allophanic downland landscape. Another set of soils could be added to this list based on observations during the 1:50,000 survey where variations in properties of these probable soils such as soil depth, drainage, and texture would suggest other possible siblings occurring in this landscape.

Table 1: Three land components of Allophanic downland landscape showing soil types mapped and complexity of these map units

Land component	Soil type NZSC (S-map sibling)	Component soils easily distinguished from each other	Land component may be further defined to help identify soils	Soils may be complexes
Easy rolling	LOT (Otorohanga_28.1)	na	na	no
Old Terraces	LOT (Otorohanga_19.8) LIT (Te Puninga_4.1) BOM* GOT (Pukehina_8.1)	yes	yes	yes
Soft Ignimbrite hill	LOT (Otorohanga_19.8) BOT (Ngatimoti_2.1) BOT*	no	yes	no

*not yet defined

Soil Windows in the Waipa

The method used to develop windows has been to look at how we can explain soil spatial patterns in the landscapes that are currently being mapped for the purposes of S-map. As outlined above, a conceptual model is initially developed by observing the general soil–landscape patterns. The conceptual model is then further refined by more detailed observations (at the farm scale) within training ‘windows’. This can be viewed as starting with a top-down approach to break the landscape into units that convey meaning and for which a number of models are proposed to describe the soil–landscape pattern observed.

This is then refined by a bottom-up approach where soil individuals are fitted into the land components and the components into a region. A soil map unit is defined by one or more constituent soil individuals, and the land component is defined by soil map units, which, in turn, define the landscape model that fits within a land region.

The Waipa catchment is currently being mapped at 1:50,000 scale for S-map and conceptual soil-landscape models are being developed in the process. Based on the current mapping, seven land regions for the catchment are proposed. It is expected that these land regions will encompass nine soil-landscape models – more than one soil-landscape model may be applicable to a single land region (Figure 4). The next step is to refine these nine models in the land regions where we believe they apply by selecting small representative soil windows at locations throughout the Waipa catchment in much the same way we developed the windows in the South Waikato outlined above. As most of these land regions are not confined exclusively to the Waipa catchment, the models developed in the Waipa will also have value where these land regions extend outside the catchment.

Further work

The South Waikato windows will be further developed to better illustrate the soil patterns in this region. This will entail producing a stylised diagram, similar to that shown in Figure 1, of a general soil-landscape model for the Upper Waikato catchment. In addition a combination of diagrams, landscape photographs and profile photographs will be will be used to illustrate specific soil-landscape relationships. In order to 'walk' through the process of soil identification, these illustrations will be accompanied by explanatory text and a key or flow diagram to enable the end user to follow a logical set of steps to identify components of the landscape and the associated soils. Finally, a comprehensive list of probable and possible alternative S-map siblings for a particular windows model will be presented as a table to allow a quick comparison between different soils and their key defining attributes in terms of both landscape position and profile morphology. The S-map sibling code will then connect these soils with the relevant factsheets in the S-map database. Over the next couple of years this process will be repeated for the Waipa catchment, and potentially for the other parts of the Waikato region as S-map surveying progresses.

Applications for Soil Windows

An objective of the Waikato Soil Windows project is to add value to S-map in the Waikato Region by making soil information more accessible to a wider audience. As the target audience is broad we envisage many ways in which this tool could be applied. As outlined above, this could be to convey quite technical pedological concepts that may be useful as a teaching aid, to refine maps, or to extend our understanding of soil–landscape processes. It has potential in the agricultural sector to build understanding of soils that can then support multiple land-management applications and decision making. As land use intensifies in the region, management of nutrients and water is becoming a major factor in farm management, with soil information at a farm-management scale emerging as an important component of farm-management plans whether these are focused on environmental or productivity outcomes.

S-map has been developed (Lilburn et al. 2011) to deliver accurate and detailed soil information at the sibling level – the 5th level in the New Zealand Soil Classification (NZSC) hierarchy (Hewitt 2010). Through use of data from the national soils database (NSD) and detailed S-map sibling data, pedo transfer functions (ptfs) are used to derive a number of useful soil attributes which can be displayed spatially or as input for various models. Soil information will continue to improve as new information is fed into national soil datasets and statistical models are improved. Waikato Soil Windows is being developed as a resource to build understanding of the regions soil resources and enable use of soil information in S-map at an appropriate scale.

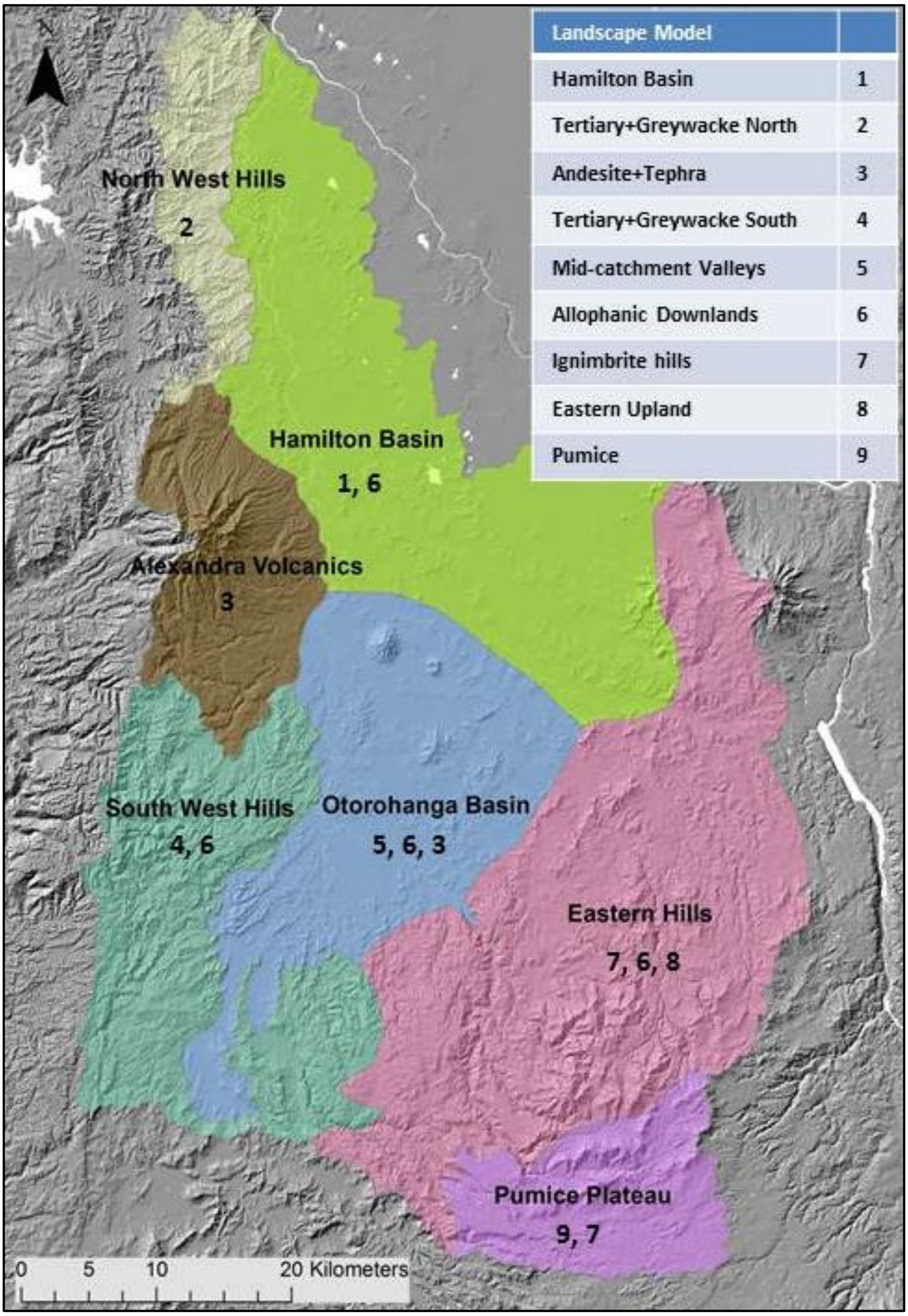

Figure 4: Waipa catchment showing proposed land regions where soil-landscape models will be developed using the soil windows approach. Note that some models will apply in more than one land region; also Hamilton Basin refers to both a model and a land region.

Summary

Waikato Soil Windows has been initiated to formalise soil–landscape relationships developed during S-map mapping, and to increase the accessibility and uptake of soil information. As S-map surveying progresses, detailed soil–landscape models are being developed to help understanding of soil landscape relationships.

A method has been outlined whereby conceptual models are developed for provisional land regions during a reconnaissance phase of soil survey that is refined as the survey progresses. The development of soil windows 'fits' soil individuals, identified during the survey, into land components and together they define a soil–landscape model that then fits within a broad land region model. Each intensively mapped area can be thought of as a discrete 'window', while a soil–landscape model can be defined by 1 or more 'windows' and relates the window/s to the wider landscape. A land region model then illustrates how the windows models fit into the broader land region.

Capturing and articulating soil-landscape relationships will assist with understanding and developing soil mapping in the future. The resolution of the spatial information in S-map (1:50,000) may be too coarse to be useful for farm- or paddock-scale management. Therefore, an understanding of the soil–landscape relationships may provide land managers with an insight into the soil pattern within a particular area. Soil windows could also be used to help develop farm-scale soil maps displaying S-map siblings, ensuring greater value could be derived from the sibling data in S-map. These data have multiple uses in the management of nutrients, water, effluent, cultivation, and grazing.

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