Sediment Dynamics in Changing Environments (Proceedings of a symposium held in Christchurch, New Zealand, December 2008). IAHS Publ. 325, 2008.

Modelling hillslope soil erosion at ANZAC Cove, Turkey

S. MATTHEWS & M. N. NEAVE
Division of Geography, School of Geosciences, University of Sydney, New South Wales 2006, Australia
m.neave@usyd.edu.au

Abstract The Gallipoli Peninsula Peace Park in Turkey is becoming an increasingly popular tourist destination, particularly around ANZAC day when thousands of Australian and New Zealand visitors attend memorial ceremonies. The Peace Park currently faces the difficult issue of balancing public access to its battlefield sites with the desire to conserve their natural and archaeological value. An important aspect of this management is a perceived need to control soil erosion, which has been identified as a problem within the Park. Although potentially important, very little work has been undertaken to determine the extent to which erosion is occurring or to quantify erosion rates. This study aims to remotely predict erosion susceptibility at ANZAC Cove, a site within the Gallipoli Peninsula Peace Park, using a hillslope soil erosion model: Silsoe. The model was built in an ArcGIS framework using a Digital Elevation Model (DEM) that enabled output in the form of erosion prediction maps. Initial results indicate that slopes around ANZAC Cove are vulnerable to extensive erosion, rates of which are primarily limited by sediment transport capacities. Some of the highest rates of erosion coincide with the occurrence of important historic sites, reflecting the significance of topography in the Gallipoli campaign. The results of this study can be used to provide an initial risk assessment for soil erosion in the Gallipoli Peninsula Peace Park and information for the emplacement of erosion control measures in the Park.

Key words Silsoe model; sediment transport; Gallipoli Peninsular Peace Park, Turkey; erosion susceptibility

INTRODUCTION

Australian and New Zealand Army Corp (ANZAC) forces landed on the Gallipoli Peninsula at Ariburnu on 25 April 1915, signalling the beginning of a nine-month military campaign against Turkish forces during World War One. In the ensuing battles, Turkey suffered approximately a quarter of a million casualties (Matthews, 2000) and, for the first time, Australian and New Zealand forces combined to fight on foreign soil—leading to the birth of the ANZAC tradition. Today, ANZAC Cove remains an important historical icon for Australia, New Zealand and Turkey, and thousands of tourists visit sites within the Gallipoli Peninsula Peace Park every year.

Managers of the Gallipoli Peninsula Peace Park, therefore, currently face the difficult issue of balancing the need to allow public access to its battlefield sites with the desire to conserve their natural and archaeological values. This is further complicated by the increasing popularity of ANZAC Cove as a tourist destination, particularly amongst Australians and New Zealanders. For example, more than 13 000 people attended the dawn service on 25 April, 2002, almost tripling the number of visitors who attended the 1995 service.

Importantly, the nature of the terrain played a significant role in the outcome of the 1915 campaign. The steep, deeply incised slopes, narrow beaches and inadequate water supplies at the ANZAC Cove landing site were major factors in the failure of the allied land campaign (Doyle *et al.*, 1999). Management of the Peace Park therefore includes the need to preserve this terrain and requires an appreciation of the extent and distribution of erosion within it (Morgan *et al.*, 1982). This is made more pertinent by the fact that the remains of Turkish and allied soldiers are buried in numerous unmarked graves distributed throughout the Park (Reid, 2000) and may be at risk in highly erosive locations. This study uses remote methods (modelling and image analysis) to predict erosion susceptibility at ANZAC Cove. The goals are to identify the apparent controls on erosion in this region and to produce erosion prediction maps that can be utilized to support management decision-making.

METHODS

Erosion rates were predicted for an approximately 6.25 km^2 area in the Gallipoli Peninsula Peace Park that encompasses ANZAC Cove, Ariburnu, Plugge's Plateau, The Nek and Lone Pine

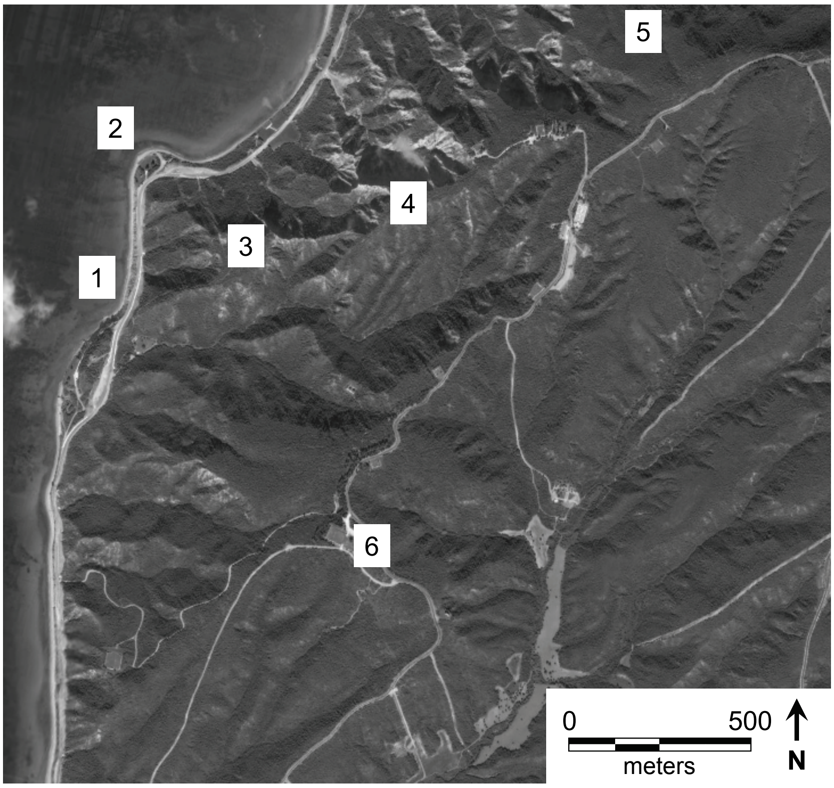

Fig. 1 Satellite image of the study area showing approximate locations of important features. 1 = ANZAC Cove; 2 = Ariburnu; 3 = Plugge's Plateau; 4 = The Sphinx; 5 = The Nek; 6 = Lone Pine.

(Fig. 1). The climate of the study region is a combination of Mediterranean and Black Sea, with hot, dry summers and warm, wet winters. The average annual temperature is 14.9°C and the average annual precipitation is 629 mm. Soils are typically coarse and highly erodible xerorthents with some haploxerepts (Ekinci & Kavdir, 2005).

The landscape has been extensively reworked by fluvial systems and is dominated by steep ridges, some of which are flat topped, and intervening flat valley floors. The region is dominated by shrub vegetation that is patchily distributed, depending upon slope. While the vegetation is relatively dense on flatter, low lying regions, it becomes extremely sparse to absent on the steep, deeply incised slopes of the valley walls.

Soil erosion at ANZAC Cove was modelled using a runoff and erosion model, known as the Silsoe model, within an ArcGIS framework. The Silsoe model is a simplified version of the Meyer & Wischmeier (1969) approach in which soil erosion is determined according to the rate of detachment of soil particles by rainsplash and the transport capacity of overland flow (Morgan *et al.*, 1982). Thus, the model predicts mean annual soil loss using the following two equations for rainsplash detachment (1) and flow transport capacity (2):

$$DET = Kd \times \{KE \times e^{-(a \times INT)}\}^{b} \quad (1)$$

$$TRAN = C \times Q^{2} \times \sin(S) \times 10^{6} \quad (2)$$

where DET is the rainfall detachment rate (g m^{-2}) and TRAN is the sediment transport capacity of overland flow (g m^{-2}). The parameters used in equations (1) and (2) are defined in Table 1. The rate of soil loss is determined by whichever of these two processes (DET or TRAN) is limiting.

Slope (*S*) for the study site was estimated using a 2-m resolution Digital Elevation Model (DEM) created from a 1916 topographic map. The Silsoe model was then run within an ArcGIS framework to generate rainfall detachment and sediment transport capacity maps that were subsequently overlaid to produce the final erosion susceptibility map.

Table 1 Input parameters used to calculate the rainfall detachment and sediment transport rates (equations (1) and (2), respectively) in the study region.

Parameter	Description	Units	Value	Reference
Kd	Soil detachability index	(–)	1.05E+00	Quansah (1981)
KE	Annual kinetic energy of rainfall	J m^{-2}	2.29E+01	Wischmeier & Smith (1978)
INT	Intercepted rainfall	%	Variable	Laflen *et al.* (1981)
C	Crop cover and management factor	(–)	5.00E-02	Wischmeier & Smith (1978)
Q	Overland flow volume per unit area	m^3 m^{-2}	2.23E-01	Kirkby (1976)
S	Slope	degrees	Variable	DEM
a	Interception exponent	(–)	5.00E-02	Laflen *et al.* (1981)
b	Splash detachment constant	(–)	1.00E+00	Morgan & Morgan (1981)

RESULTS AND DISCUSSION

Erosion modelling indicates that the transport capacity of overland flow is generally the limiting control on soil erosion in the Gallipoli Peninsula Peace Park. Soil erosion rates showed considerable variation across the site, ranging from 0.235 g m^{-2} in the flat, low lying areas to 2300 g m^{-2} on the steep slopes (Fig. 2). Thus, the most significant contributor to overall erosion rates in the Park appears to be slope. This is largely a result of the more or less uniform nature of some of the other factors that influence erosion rates within the Park (including vegetation cover, which is relatively sparse throughout the Park, and the nature of the soils, which are a coarse granular type reflecting the underlying geology—primarily of sandstone, shale and thin limestone, and are highly erodible when the vegetation is removed).

An analysis of erosion predictions indicate that the northwestern corner of the study area, which includes the popular tourist destinations of ANZAC Cove, the Sphinx, Plugges Plateau and the Nek, have the highest susceptibility to erosion (Fig. 3). The slopes in this region were often both very steep and devoid of vegetation, making their soils extremely vulnerable. Hillslope

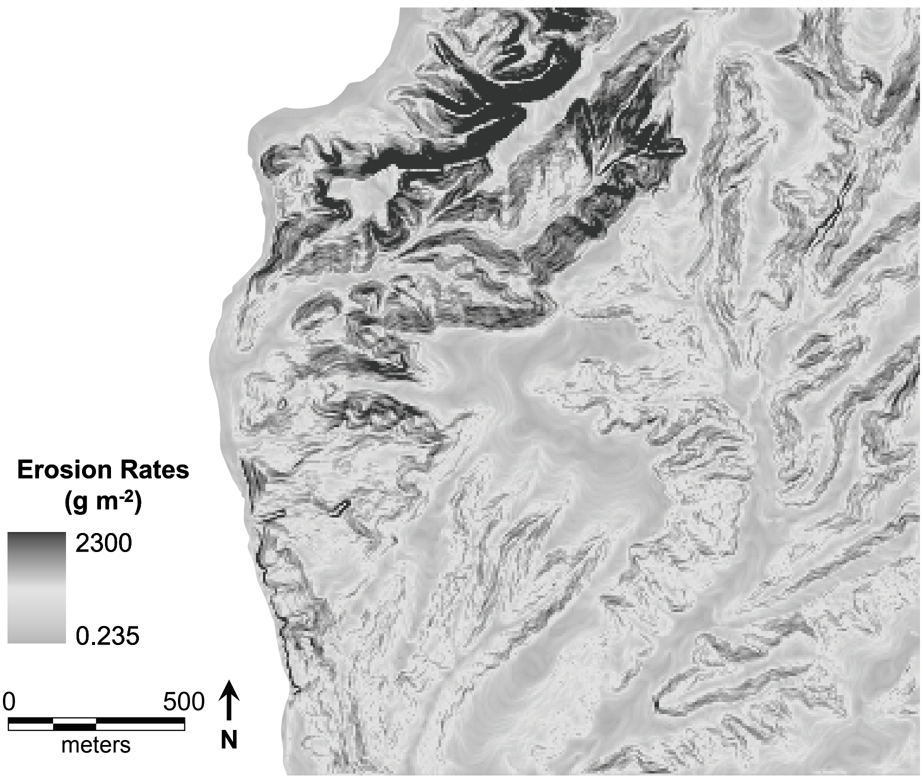

Fig. 2 Distribution of soil erosion rates predicted using the Silsoe model.

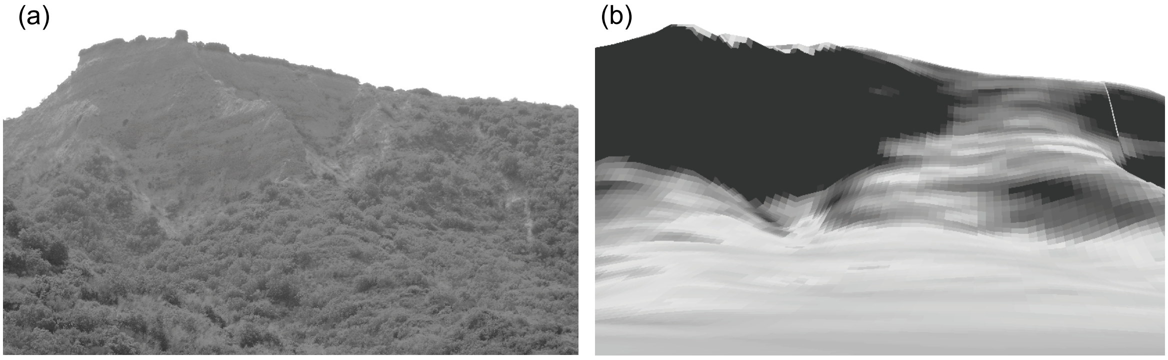

Fig. 3 View of Plugge's Plateau: (a) showing the relationship between slope and vegetation cover, and (b) soil erosion rates predicted using the Silsoe model showing extreme rates for the steep, unvegetated surfaces.

erosion, therefore, is threatening the integrity of important battlefield sites in the Gallipolli Peace Park, and has the potential to significantly degrade the overall conservation value of the site.

The potential erosion rates identified in this study highlight the need for a comprehensive erosion management plan for the Gallipoli Peninsula Peace Park. Indeed, the sparse and fragile vegetation cover is susceptible to damage from visitors and, once removed, could promote high rates of localised erosion. This has already been observed in certain locations in the Park where overuse has led to erosion that has resulted in the exposure of previously buried archaeological artefacts and even human remains. This study identifies the areas most vulnerable to this type of erosion and could be used as the basis for erosion control initiatives, such as selective fencing of mid-steep slopes, improved path construction and an education programme to inform visitors of the importance of avoiding vulnerable areas. Such a programme would ensure the on-going protection of this culturally significant site.

REFERENCES

Doyle, P. & Bennett, M. R. (1999) Military Geography: the influence of terrain in the outcome of the Gallipoli Campaign, 1915. *The Geographical J.* **165**, 12–36.

Ekinci, H. & Kavdir, Y. (2005) Changes in soil quality parameters after a wildfire in Gelibolu (Gallipoli) National Park, Turkey. *Fresenius Environmental Bull.* **14**(12), 1184–1191.

Kirkby, M. J. (1976) Hydrological slope models: the influence of climate. In: *Geomorphology and Climate* (ed. by E. Derbyshire), 247–267. Wiley, Chichester, UK.

Laflen, J. M., Moldenhauer, W. C. & Colvin, T. S. (1981) Conservation tillage and soil erosion on continuously row-cropped land. In: *Crop Production with Conservation in the 80s*, 121–133. ASAE, St Joseph, Michigan, USA.

Matthews, C. (2000) The Gallipoli Campaign: An overview. In: *Gallipoli: A Battlefield Guide* (ed. by P. Taylor & P. Cupper), 27–37. Kangaroo Press, Kenthurst, Australia.

Meyer, L. D. & Wischmeier, W. H. (1969) Mathematical simulation of the process of soil erosion by water. *Trans. Am. Soc. Agric. Engrs* **12**, 754–758, 762.

Morgan, R. P. C. & Morgan, D. D. V. (1981) Problems validating a Meyer-Wishchmeier type soil erosion model with field data. In: *Soil Conservation: Problems and Prospects* (ed. by R. P. C. Morgan), 327–334. Wiley, Chichester, UK.

Morgan, R. P. C., Hatch, T., Sulaiman, W. & Harun, W. (1982) A simple procedure for assessing soil erosion risk: A case study for Malaysia. *Z. Geomorph. N.F. Suppl.-Bd* **44**, 69–89.

Quansah, C. (1981) The effect of soil type, slope, rain intensity and their interactions on splash detachment and transport. *J. Soil Sci.* **32**, 215–224.

Reid, R. (2000) *'A duty clear before us': North Beach and the Sari Bair Range, Gallipoli Peninsula: 25 April–20 December 1915*. Dept of Veterans' Affairs, Canberra, ACT.

Wischmeier, W. H. & Smith, D. D. (1978) *Predicting Rainfall Losses: A Guide to Conservation Planning*. USDA Agricultural Handbook no. 537.