A GIS-Based Landslide Susceptibility Area Decision-Making using an Analytical Hierarchy Process: Case Study at Tamborine Mountain, Gold Coast

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Introduction

Tamborine Mountain is one of populated area in Southern Queensland which recently settled around 8500 residents. It is located on the southern part of the Moreton geological complex (Willmott, 1981) on the southwest of the City of Gold Coast. As a volcanic plateau surrounded by steep slopes, scarps, and benches stretched away from the south to the north (Green, 1964), Tamborine being one of tourism destination in Gold Coast, however, the geological and topography condition support to generate landslide hazards. It was reported a number of **earthslides and rockfalls** wrecked public and private facilities surround the flanks, which are about **5 landslides data recorded** on the **Table 1.** Previous research study about landslide hazards was established as below:

- Willmott (1981) who explained about landslide characteristics and zoning landslide susceptibility based on geology, hydrogeology, and terrain condition.
- Geotechnical study on slope stability was brought by Ali et al (2013);
- Kim et al (2014; and
- Gratchev (2022).

QUT and TMR Queensland has been collaborating to develop Landslide Early Warning System in Tamborine's critical slopes, nevertheless, which slopes that categorized as 'critical' or 'susceptible' to landslide is not defined yet.

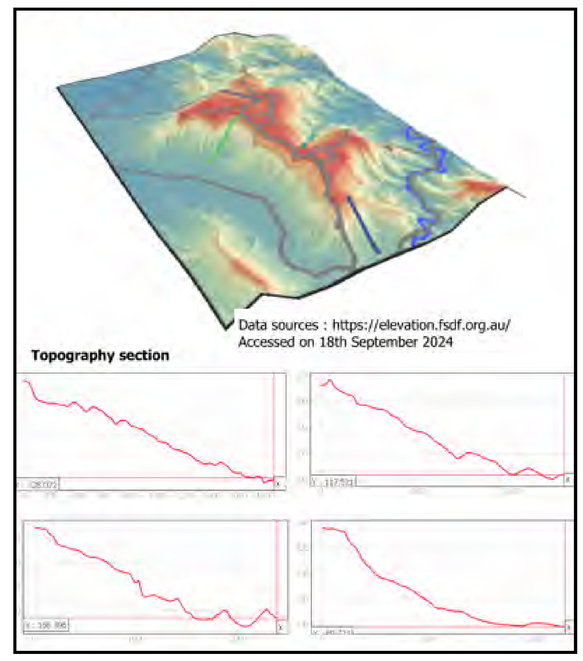
Tamborine Mountain Landslide Data

Date	Location	X	Y	Landform	Movement type	Causes	Sources
N/A	Tamborine Mt, at the back of St Bernard Hotel	518001.34	6908322.89	Escarpment	Rockfall	Surface erosion/ weathering	Willmott (1981)
N/A	Tamborine Mountain, 1km to the east of St Bernards Hotel	518001.35	6908322.90	Escarpment	Rockfall	Surface erosion/ weathering	Willmott (1981)
N/A	Tamborine Mountain, on the bench above Camerons Falls	518001.36	6908322.91	Escarpment	Earthslide	Surface erosion/ weathering	Willmott (1981)
27-01-2013	The Goat Track (Main Western Road service road, Tamborine Mountain Road), Tamborine Mountain	516923.49	6911315.37	Constructed slope	Debris	Prolonged high precipitation (Intense short period rainfall)	Media report
00-01-2013	Henri Robert Drive, Clagiraba, QLD	522803.65	6905813.21	Open-cut slope	Rockfall	Heavy rainfall	Kim et al (2015))

Research Question??

"Which areas are most susceptible to landslides and rockfalls?"

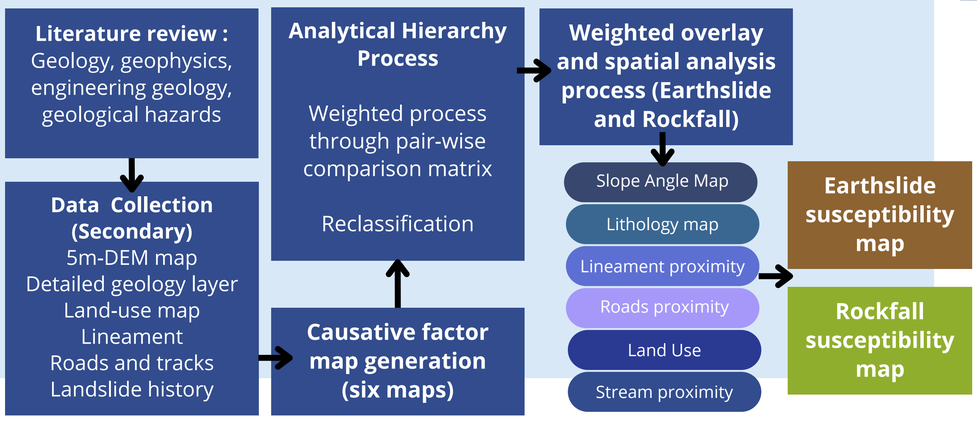
3D Physiography map of Tamborine Mountain



Methods

Due to limited of landslide history data, *data-based driven* decision is not applicable. Therefore, susceptibility mapping was done by a *knowledge-based driven* method. Semi-qualitative decision-making process was applied using **Analytical Hierarchy Process (**Saaty, 1980; Rozos et al., 2011, as cited in Gulbet et al, 2024 **).** It is a heuristical process that combined qualitative judgement of expertise and quantitative. This method **controls the uncertainty** from our judgement through the **'Consistency Ratio' rule** (Soeters et al 1996; Guzetti et al 1999; as cited in Liu, X. et al 2024)

Research Flowchart



AHP Method

Data Aspect and Sources

Importance scale	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6,8	Intermediate values between two adjacent decisions
Reciprocals	Used for inverse comparison

n	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49	1,51

Data Analysis

Data Aspect and Sources

Data aspect	Data format	Remarks	Source
Slope angle	Raster	Derived from 5m DEM; divided by degree unit; EPSG:7856 - GDA2020 / MGA zone 56 -	Geoscience Australia 2015
Land use	Raster	The most recent mapping of land use features for South East Queensland from 2011, 2012 and 2013; EPSG:7856 - GDA2020	Department of Environment and Science, Queensland Government 2023
Lithology	Raster	EPSG:7856 - GDA2020 / MGA zone 56 - Projected	Department of Resources Queensland 2023
Lineament Proximity	Raster	EPSG:7856 - GDA2020 / MGA zone 56 - Projected; proximity processing derived from	Department of Resources Queensland 2023
Stream proximity	Raster	EPSG:7856 - GDA2020 / MGA zone 56 - Projected; proximity processing derived from	Queensland Spatial Catalogue
Road Proximity	Raster	EPSG:7856 - GDA2020 / MGA zone 56 - Projected; proximity processing derived from	Department of Resources Queensland 2023
Landslide location	Point shapefile	Some points was adjusted referring to Willmott (1981) - EPSG:7856 - GDA2020 /	Geosciences Australia (2012); Kim, D.H et al (2015)

Pair-wise comparison matrix for causative factors

Pair-wise comparison matrix for earthslide susceptibility zonation

Criteria	Sl	Lt	LP	LU	RP	SP	Weight	CR
Sl	1,00						0,30	
Lt	0,50	1,00					0,24	
LP	0,50	0,50	1,00				0,19	8,7%
LU	0,50	0,50	0,50	1,00			0,14	
RP	0,33	0,67	0,33	0,50	1,00		0,10	
SP	0,20	0,40	0,25	0,25	0,33	1,00	0,05	

Pair-wise comparison matrix for rockfall susceptibility zonation

Criteria	Lt	Sl	LP	LU	RP	SP	Weight	CR
Lt	1,00						0,32	
Sl	0,50	1,00					0,26	
LP	0,50	0,50	1,00				0,17	9,3%
LU	0,33	0,33	0,50	1,00			0,12	
RP	0,25	0,50	0,33	0,50	1,00		0,08	
SP	0,20	0,40	0,25	0,25	0,33	1,00	0,05	

Sl = Slope Angle; Lt = Lithology; LP = Lineament Proximity; LU = LandUse; RP = Roads Proximity; SP = Stream Proximity

Pair-wise comparison matrix for slope angle factor (Earthslide) in degree

Criteria	>45	35-45	25-35	15-25	<15	Weight	CR
>45	1,00					0,37	
35-45	0,50	1,00				0,26	
25-35	0,50	0,50	1,00			0,19	2,9%
15-25	0,33	0,33	0,50	1,00		0,11	
<15	0,25	0,33	0,33	0,50	1,00	0,07	

Pair-wise comparison matrix for slope angle factor (Rockfall) in degree

Criteria	>45	35-45	25-35	15-25	<15	Weight	CR
>45	1,00					0,42	
35-45	0,50	1,00				0,28	
25-35	0,33	0,50	1,00			0,19	8,0%
15-25	0,17	0,20	0,25	1,00		0,08	
<15	0,14	0,14	0,17	0,25	1,00	0,04	

Pair-wise comparison matrix for lithology factor (Earthslide) in degree

Criteria	Cl	Al	BR	CS	Ar	MR	Weight	CR
Cl	1,00						0,34	
Al	0,50	1,00					0,26	
BR	0,50	0,50	1,00				0,19	5,0%
CS	0,33	0,33	0,33	1,00			0,10	
Ar	0,17	0,20	0,25	0,50	1,00		0,06	
MR	0,17	0,20	0,25	0,33	0,33	1,00	0,04	

Pair-wise comparison matrix for lithology factor (Rockfall) in degree

Criteria	Cl	Al	BR	CS	Ar	MR	Weight	CR
Cl	1,00						0,32	
Al	0,50	1,00					0,25	
BR	0,50	0,50	1,00				0,17	6,1%
CS	0,33	0,33	0,50	1,00			0,12	
Ar	0,33	0,33	0,50	0,50	1,00		0,10	
MR	0,14	0,14	0,17	0,20	0,20	1,00	0,03	

Cl= Colluvium; Al= Alluvium; BR= Basaltic Rock; CS=Clayey Sedimentary rock; Ar= Arenite; MR;= Metasediment Rock

Pair-wise comparison matrix for land use factor

Criteria	IU	Wt	PI	PD	PN	CN	Weight	CR
IU	1,00						0,39	
Wt	0,50	1,00					0,24	
PI	0,33	0,50	1,00				0,16	6,3%
PD	0,33	0,33	0,33	1,00			0,09	
PN	0,25	0,33	0,25	0,50	1,00		0,07	
CN	0,25	0,25	0,25	0,33	0,33	1,00	0,05	

IU= Intensive Uses; Wt= Water; PI= Production from Irrigated Agriculture and Plantations; PD= Production from Dryland Agriculture and plantations; PN= Production from relatively Natural environments; CN=

Pair-wise comparison matrix for roads proximity factor

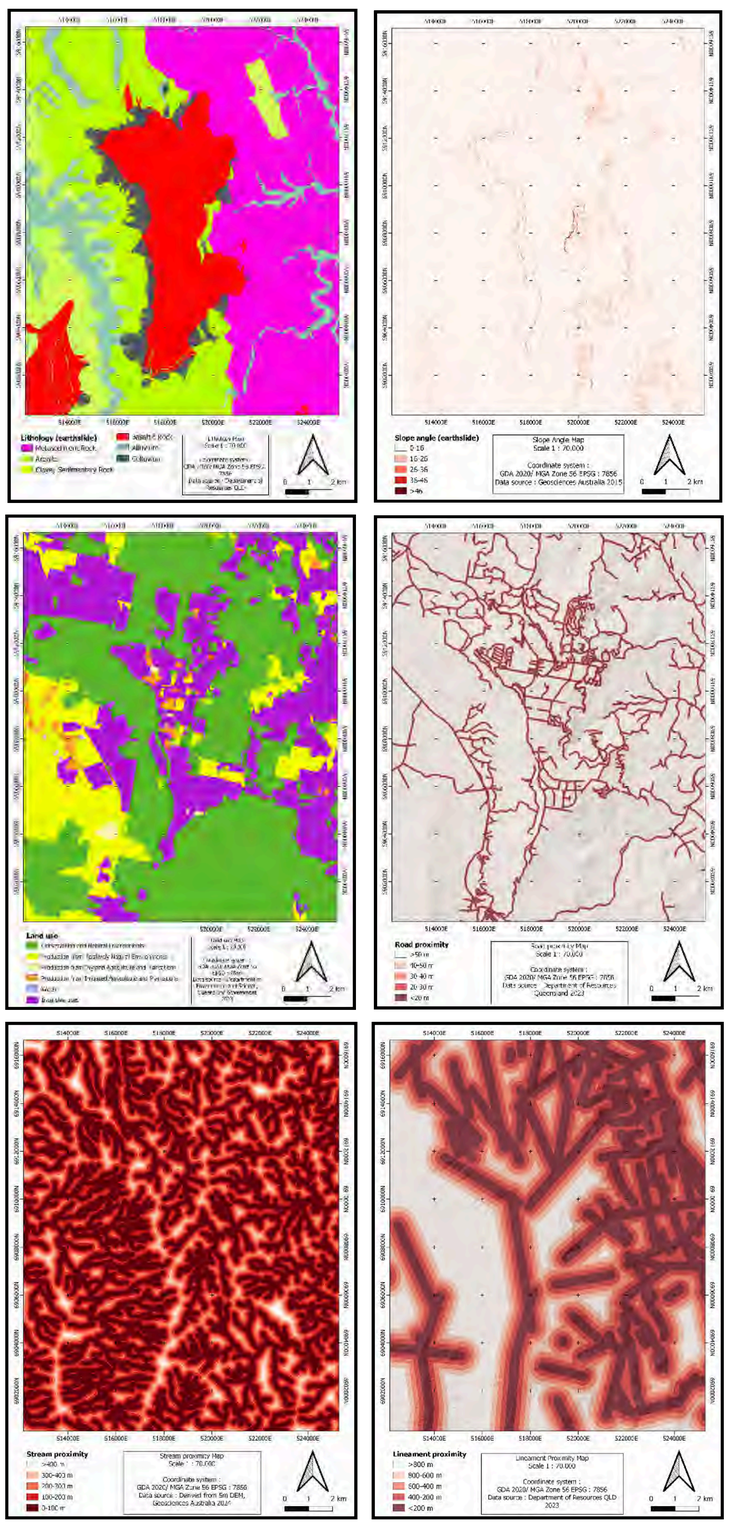
Criteria	0-20m	20-30m	30-40m	40-50m	>50m	Weight	CR
0-20m	1,00					0,36	
20-30m	1,00	1,00				0,29	
30-40m	0,33	0,50	1,00			0,18	3,2%
40-50m	0,33	0,50	0,50	1,00		0,13	
>50m	0,14	0,17	0,20	0,25	1,00	0,04	

Pair-wise comparison matrix for stream proximity factor

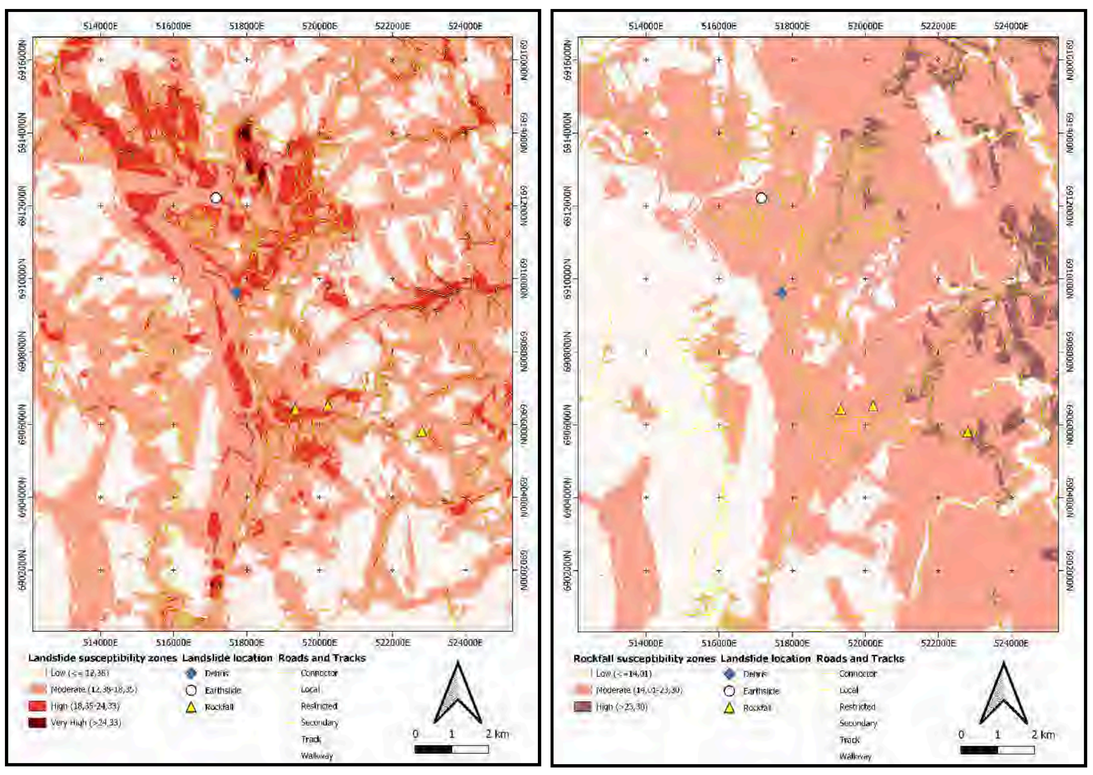
Criteria	0-100m	100-200m	200-300m	300-400m	>400m	Weight	CR
0-100m	1,00					0,37	
100-200m	1,00	1,00				0,32	
200-300m	0,33	0,50	1,00			0,18	4,5%
300-400m	0,20	0,25	0,33	1,00		0,09	
>400m	0,17	0,20	0,25	0,33	1,00	0,05	

Pair-wise comparison matrix for lineament proximity factor

Criteria	0-200 m	200-400 m	400-600 m	600-800 m	>800 m	Weight	CR
0-200 m	1,00					0,35	
200-400 m	0,50	1,00				0,27	
400-600 m	0,50	0,50	1,00			0,19	3,9%
600-800 m	0,33	0,33	0,50	1,00		0,11	
>800 m	0,33	0,33	0,33	0,50	1,00	0,08	



Result and Discussion



Rockfall Susceptibility Zone

Class	Areas (Km2)	Rockfall
Low	103,69	0%
Moderate	168,26	0%
High	4,50	100%

Earthslide Susceptibility Zone

Class	Areas (Km2)	Earthslide
Low	107,46	0%
Moderate	147,87	0%
High	21,09	100%
Very High	0,04	0%