Teaching & Learning Step-by-Step Guide:

Modeling the Future Land Use Change using MOLUSCE



Amila Jayasinghe Yohan Senawirathna Sulakshana Abeywardhana Samith Madusanka **Teaching & Learning Step by -Step Guide:**

Modeling the Future Land Use Change using MOLUSCE

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Publisher

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PREFACE

This book serves as an open educational resource for both undergraduate and postgraduate degree programs, offering a detailed, step-by-step guide to modeling future land use change using the MOLUSCE plugin in QGIS. Designed to bridge the gap between theoretical knowledge and practical application, this guide is meticulously crafted to meet the needs of students, educators, and practitioners alike.

Within the book, readers will find comprehensive instructions on utilizing advanced algorithms such as Artificial Neural Networks (ANN), Logistic Regression (LR), and Weight of Evidence (WoE) to analyze and predict future land use changes. The guide provides detailed processes for ingesting raster data representing historical land use patterns and pertinent explanatory variables, training predictive models, and simulating future land use scenarios.

The book not only enhances learning in academic settings by providing real-world applications and case studies but also equips industry professionals with the skills necessary to conduct advanced spatial analysis and contribute meaningful insights in their fields. By understanding and managing land use dynamics, users can anticipate and plan for changes, facilitating informed decision-making in areas such as urban planning, natural resource management, and environmental conservation.

Whether you are a student aiming to master land use modeling and geographic information systems, a teacher looking for robust educational tools, or a practitioner in need of refining your technical expertise, this book offers invaluable guidance and support. It ensures that users at all levels gain proficiency in leveraging modern technologies to explore and solve geographic challenges effectively, empowering proactive planning and management of land resources for resilient and sustainable landscapes.

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CHAPTER 1: INTRODUCTION

1.1 Modeling the Future Land Use Change using MOLUSCE

MOLUSCE (Modules for Land Use Change Simulations) is a powerful plugin designed to analyze and predict future land use changes within specific regions. Utilizing advanced algorithms such as Artificial Neural Networks (ANN), Logistic Regression (LR), and Weight of Evidence (WoE), MOLUSCE integrates various spatial and non-spatial factors to simulate land use dynamics over time. By ingesting raster data representing historical land use patterns and pertinent explanatory variables, MOLUSCE trains predictive models to forecast future land use scenarios.

This modeling approach offers several benefits for understanding and managing land use change. Firstly, MOLUSCE provides valuable insights into the potential impacts of various socio-economic, environmental, and policy factors on land use dynamics. By simulating future scenarios, allows stakeholders to anticipate and plan for changes in land use patterns, facilitating informed decision-making in areas such as urban planning, natural resource management, and environmental conservation. Additionally, MOLUSCE enables the assessment of different land management strategies and policy interventions, helping to identify optimal pathways for sustainable land use development.

MOLUSCE empowers users to explore and visualize future land use changes, enabling proactive planning and management of land resources for resilient and sustainable landscapes.

Equipment/s	Software/s	Inputs
 Equipment/s Computer A computer with sufficient processing power and memory is necessary to run QGIS and MOLUSCE efficiently, especially when dealing with large datasets or complex analyses. There are no strict formal system requirements. It is recommended to have a computer with modern specifications to ensure smooth performance. 	Software/s QGIS Desktop 3.22.7 QGIS 3.0 or later can be used for data preparation works QGIS Desktop 2.18.15 QGIS Desktop 2.18.15 Output Users can download and install the plugin from the QGIS Plugin Repository here. QGIS Platform Overview Type: Open-source	 Inputs Inputs Imputs Imput
Table 1 -Required Items for Study	 Installation: Available for Windows, macOS, Linux 	

1.2 Required Equipment/s, Software/s, and Inputs

Table 1 -Required Items for Study

1.3 Final Result of the Modeling

Our modeling process using MOLUSCE has provided a clear picture of what Dambulla's landscape could look like in 2035. We used data from 2005 and 2020 to predict how land use will change in the future. By looking at various spatial and non-spatial factors such as environmentally sensitive areas, land use efficiency of the area, accessibility, access to basic services, and population density, we have made some strategic assumptions about how the land in the Dambulla region will be used in the coming years.

The results show us where things might stay the same and where big changes could happen. This helps us understand how our cities might grow, how agricultural activities might change, and how we can protect our environment better. By knowing what could happen, we can make better plans for the future, ensuring our landscapes are healthy and sustainable for years to come.

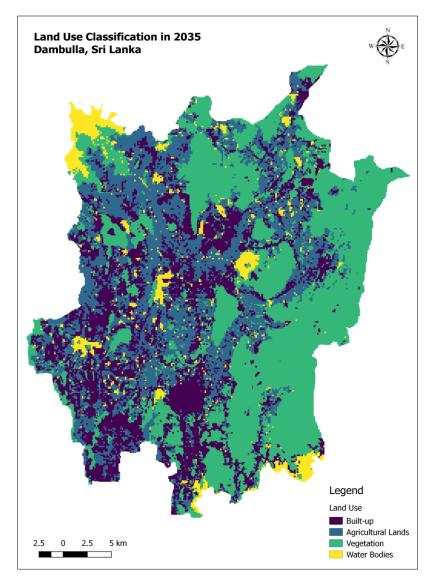
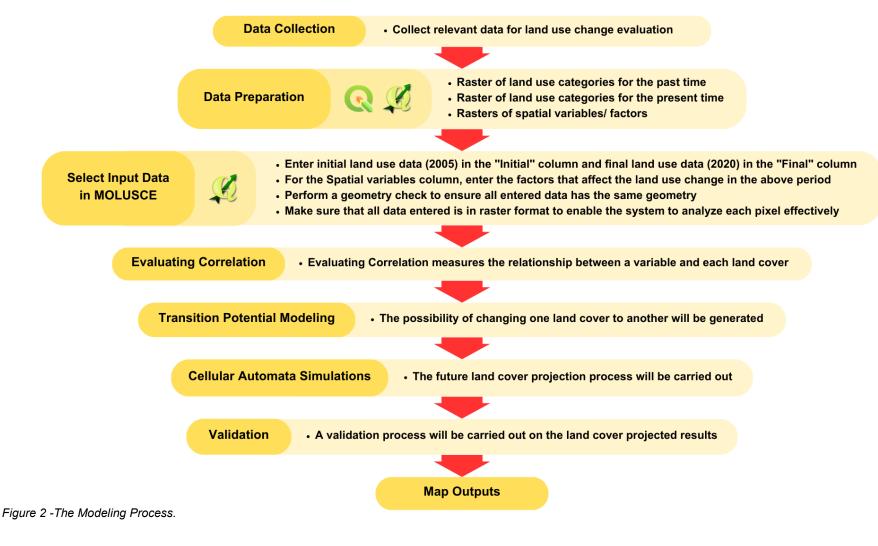


Figure 1 -Final Result of the Modeling

1.4 Data Preparation and Modeling Process



CHAPTER 2: DATA PREPARATION

Example Study Area

For this exercise, the Dambulla Regional area has been selected as the example study area. This is one of the major cities according to the National Physical Plan for 2050. Greater Dambulla Regional Boundary was introduced under this National Physical Plan of Sri Lanka, and it is to be used in this exercise.

Data Collection

By conducting a field visit in the Dambulla area, we identified its special characteristics. One of the special things that we focused on while doing the study was how the future land use pattern could be. Accordingly, we studied a considerable amount of past land use patterns and current land use patterns in this area. After collecting a certain amount of data with the help of local residents, we engaged in further studies with the help of local-level institutions and officials.

Additionally, we obtained some pre-processed datasets from government agencies such as the Urban Development Authority, Sri Lanka Mahaweli Authority, and the National Building Research Organization.



Figure 3 -The Study Area

2.1 Preparation of the Land Use Layers

To model the future land use change of a particular area using MOLUSCE, it is necessary to select a period and prepare relevant land use raster layers. These land use layers must be classified under certain major land uses. A high count of land use categories may cause errors while using MOLUSCE. In this exercise, the period considered here is from **2005 to 2020**, to predict the future land use change, and we used the classified land use layers for the years 2005 and 2020 separately. **Both the layers should have the same land use categories**. However, there is a practical possibility that one or more land use categories that did not exist in 2005 will be added by 2020.

In this situation, we cannot see that kind of scenario and the **Built-up areas**, agricultural lands, vegetation layers, and water bodies are the categories that are included in these layers that we have used.

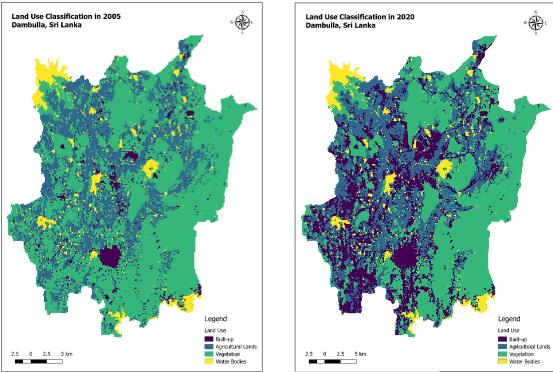


Figure 5 -Land use layer for the year 2005

Figure 4 - Land use layer for the year 2020

Looking at the preparation of these two layers, the vector layers should be prepared first. Here we were able to obtain two pre-processed vector layers for the years 2005 and 2020 through their associated government agencies. If you are trying to make a land use prediction for an area like this, first find out if the area has pre-processed land use vector layers. Once you have gotten them, you can present the land use categories as needed through tasks such as updating their attribute tables.

The standard categorization of land uses can be shown as follows. If you are looking to do a detailed land use classification, Level 3 categorization is best for that. When it comes to Level 2, land uses are quite compact, and a collection of several land uses mentioned in Level 3 is included here in one category.

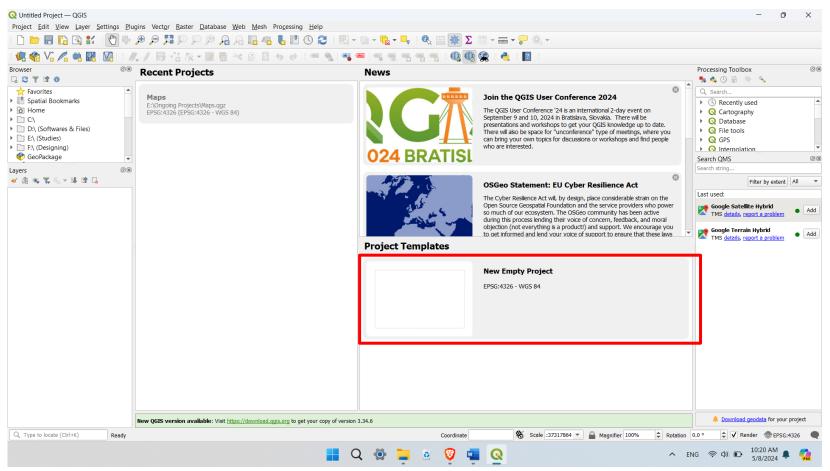
Level 1	Level 2		Level 3
Build up Non-built-up	Business Commercial Education Government (Institutional) Health Industries/Distribution Open Land Other Residential Roads Transport Wetland	Airport Animal Clinics Bakery / Spa / Saloon/laundry / Shops and Houses Bank Bare Land (Land Sale / Non-Use Land / Etc.) Borrow Pits Bus Depot Bus Stands Cemetery Child Education Centers / Child Day Care Centers Church Condominium Scheme Conference & Exhibition Centers Construction Office & Yards Construction Site Corporations Court Houses Departments / Boards / Authorities Elderly Homes Embassy Financial Support Institution / Insurance Company Fuel Stations Garments General Hospital (Large Size Hospital)	Government Quarters Health Care Centers Hostels & Domes Hotel & Motel Hotel with More than 100 Rooms Housing Scheme More than 10 Houses Housing Scheme More than 100 Houses Individual Private Houses / Dwelling Houses International School / Private School Kovil Lakes Logistics and Distribution Centers Low-Income Houses Manufacturing Plants Market Marshy Medium Size Hospitals (District/Military Hospitals) Metal Quarry Military Admin Office Ministries Mosque Motor Vehicle Yard Museum Library

Table 2 – Standard Land Use Categorization

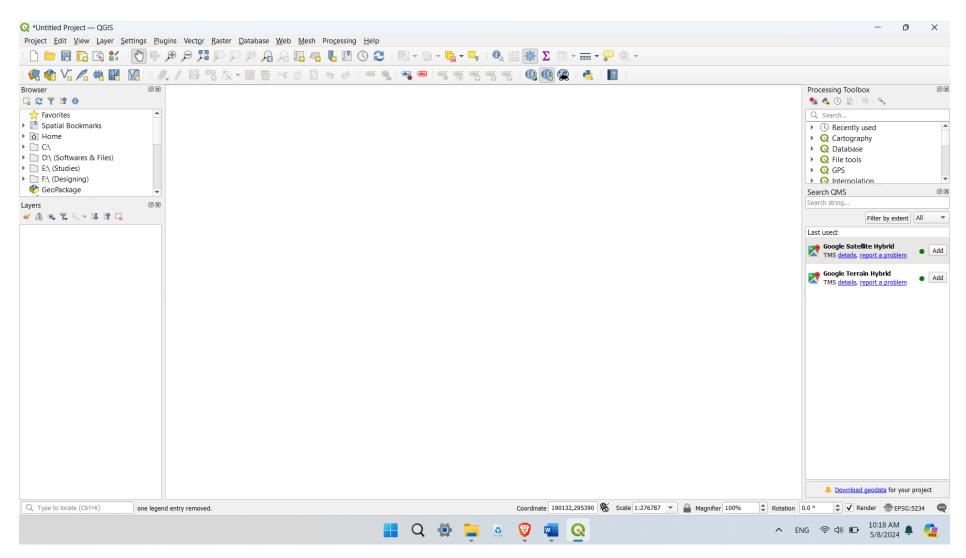
Regarding the Dambulla area, we mainly identified 4 land use categories. This can be expressed as a level 2 type of categorization because many types of land uses are shown in this one category here. For this categorization of the layer, first, we open the 2020 land use vector layer from the 2005 and 2020 land use layers through the QGIS 3.22.7 version. You can use any version of QGIS for this.

Step 01 -

1.1 Open the QGIS on your computer and click on "New Empty Project".



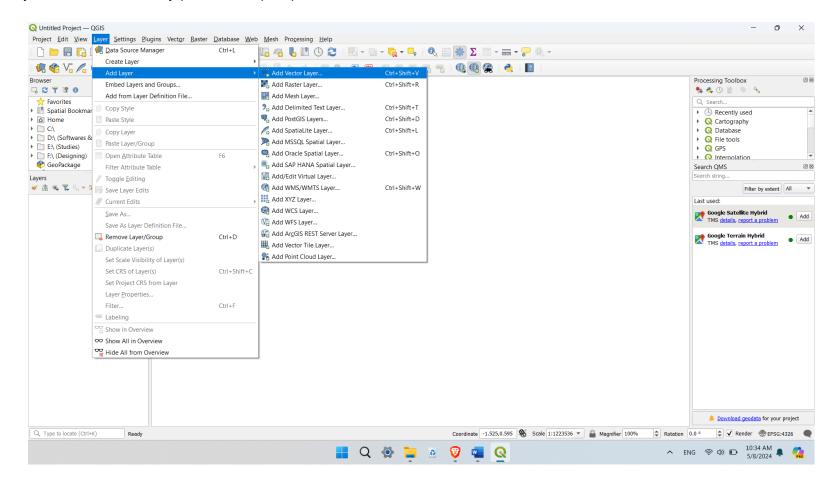
1.2 Then the workspace will be shown as follows on your screen. Next, we have to import the relevant vector layer.



Step 02- Importing vector layers into QGIS

1.1. You can open your vector files with QGIS in the following way using the layer toolbar. (Layer > Add Layer > Add Vector Layer)

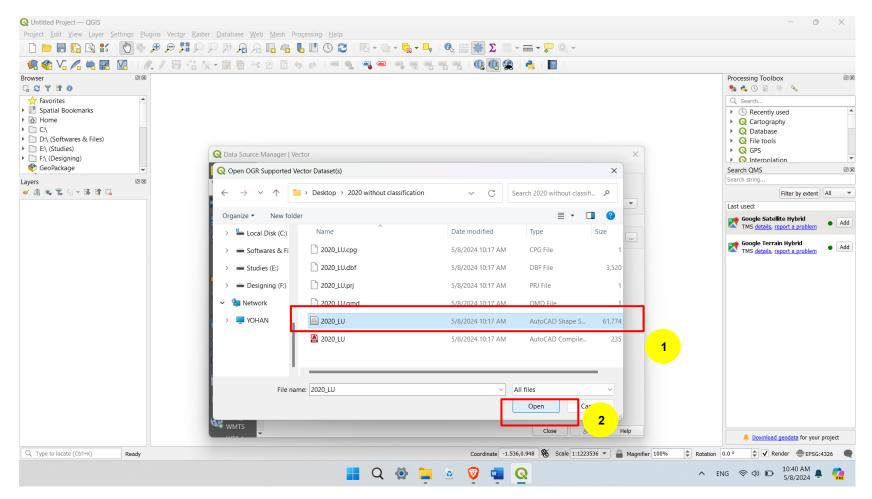
Otherwise, you can use the short key (Ctrl+Shift+V) to open the vector files.



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1.2. Then the following window will appear on the screen. You have to browse the location that the data files stored on your computer.

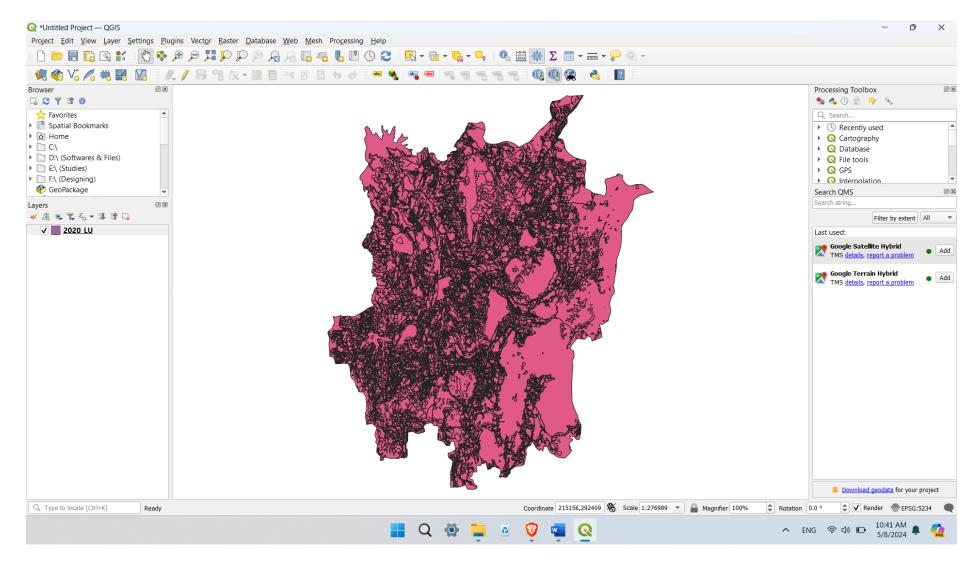
2.3 After clicking on "**Browse**", the following window will open. Then, go to the relevant folder and select the vector file. Usually, a shape file consists of 6 other files. The file type you should choose to open here is the "**AutoCAD Shape Source**" file. As per the instructions, click on that layer, and after that click on "**Open**".



2.4 Again, click on "**Add**" to add the layer to the workspace.

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2.5 The land use layer will appear on the screen as follows.

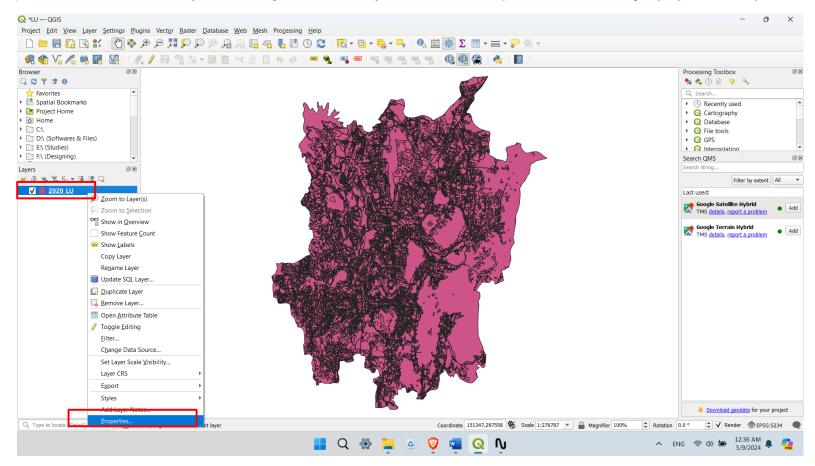


14 | Page

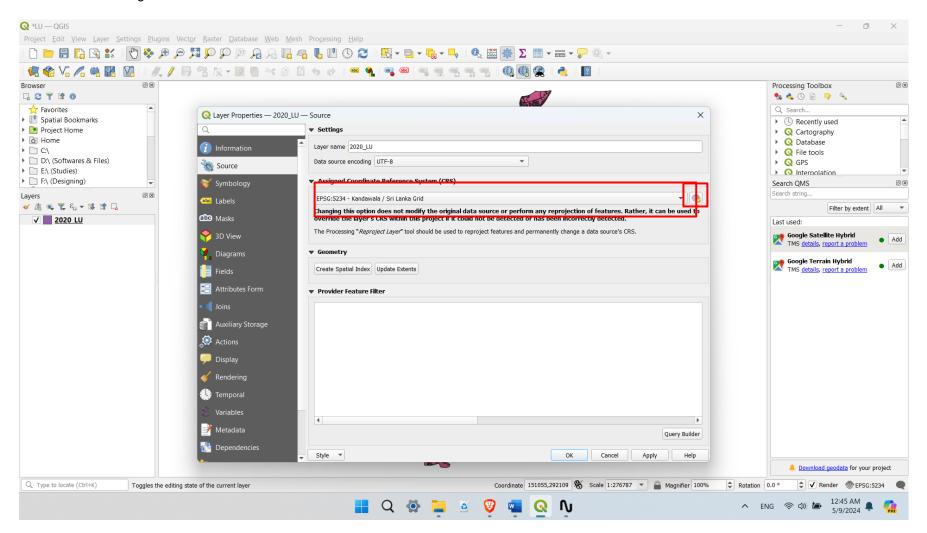
Step 03– Setting up the Coordinate Reference System (CRS)

The Coordinate Reference System of all the layers used for this land use prediction should be the same. The first thing we prepare in this way is the Land Use Layers. Here we choose a Coordinate Reference System for this layer, this Coordinate System must be used for all the layers prepared from now on.

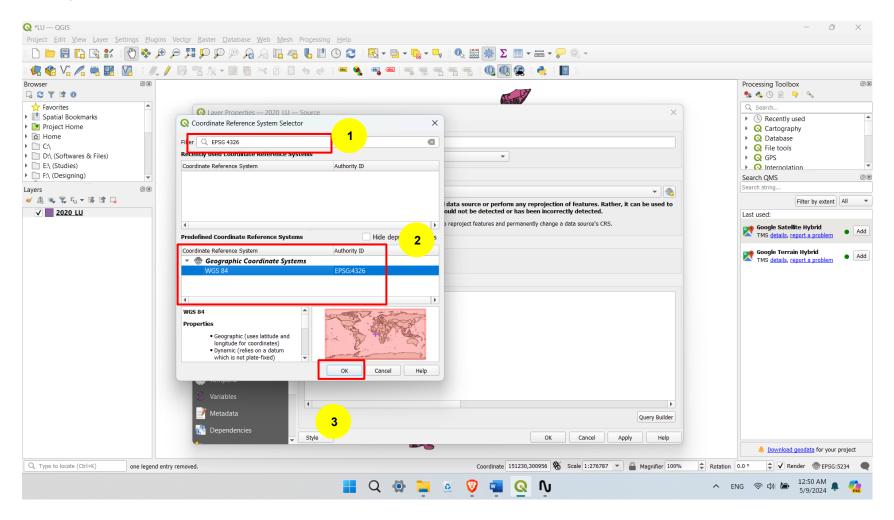
3.1 To set up the Coordinate Reference System, first, right-click on the layer, and click on "Properties". Then, the layer properties will open.



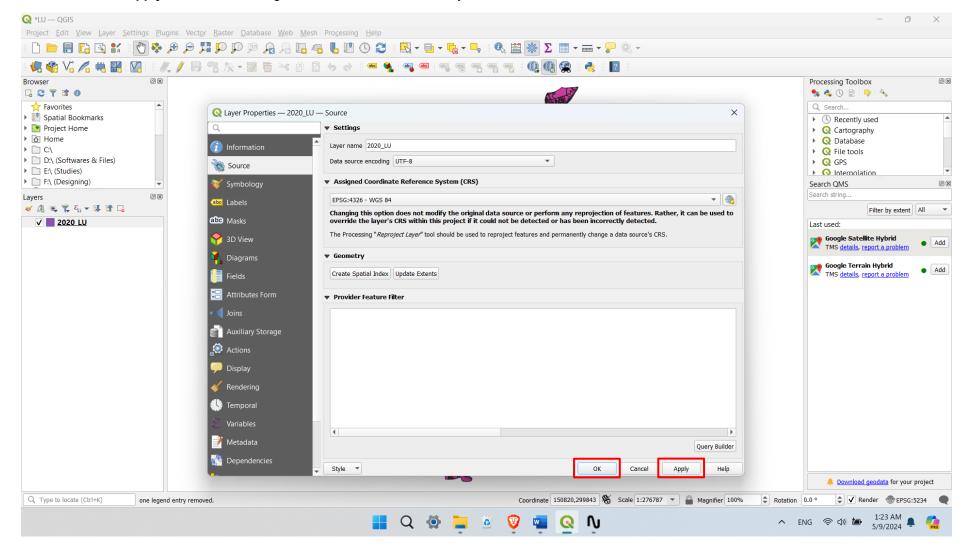
3.2 Under the "**Source**" tab, the assigned coordinate reference system can be seen. If you want to change CRS, click on the icon near the position that the current CSR showing.



3.3 Then, the following "**Coordinate Reference System Selector**" window will open. In this scenario, "**EPSG 4326**" is the CRS that we want to select. For that, type the name in the search bar as follows. Then the CRS will appear under the "Predefined Coordinate Reference Systems". Simply click on that and click "**OK**" to proceed.

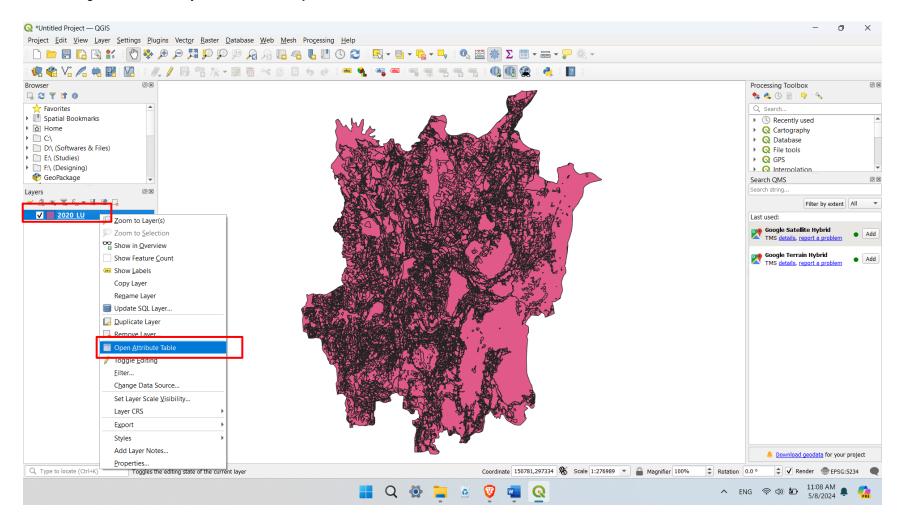


3.4 Now click on "Apply" and "OK" to change the Coordinate Reference System.



Step 04 – Functions related to updating the Attribute Table

4.1 Now, right-click on the layer and click on "Open Attribute Table".



4.2 The Attribute Table of the layer will open as follows. Under the column "**Mainuse**", we can see the land use of every plot of the Dambulla regional area.

	-		ed: 30028, Selected: 0			
	OBJECTID	OBJECTID_1	Nainuse	Shape_Leng	🗃 🗊 🔍 Shape_Area	Area_sqkm
1	1	ODICTID_1	1 Industrial		99786.7465299	Area_sqkiii 0.1
2	2		2 Paddy	2717.67941999	251126.744306	0.25
3	3		3 Agricultural Land	4929.18311977	291030.995952	0.29
4	4		4 Paddy	1689.17215193	46418.2899355	0.05
5	5	:	5 Paddy	2364.41997102	86727.6790549	0.09
6	6		6 Home Garden	314.63028272200	37431.2117259	0.04
7	7		7 Home Garden	919.44471945600	38852.2709675	0.04
8	8	;	8 Home Garden	1713.60641774	128459.212545	0.13
9	9		9 Home Garden	935.08365697200	47755.4623128	0.05
10	10	1	0 Home Garden	1118.61209198	24640.2263927	0.02
11	11	1	1 Home Garden	1201.28654152	23049.3427363	0.02
12	12	1	2 Forest	21616.1077983	10599354.3021	10.60
13	13	1	3 Home Garden	852.31742858300	18421.4767636	0.02
14	14	14	4 Forest	17135.8491440	5175386.43554	5.18
15	15	1	5 Mixed Crop	1137.08316880	32271.8629505	0.03
16	16	1	6 Paddy	1350.51420227	57605.5593162	0.06
17	17	1	7 Home Garden	1845.31383046	79789.0108553	0.08
18	18	1	8 Home Garden	1733.71833854	138862.127201	0.14
19	19	1	9 Home Garden	1445.51485434	67613.2591164	0.07
20	20	2	0 Home Garden	2270.19326061	58704.0006069	0.06
21	21	2	1 Mixed Crop	1326.44501681	40951.2535784	0.04
22	22	2	2 Agricultural Land	1969.55971315	79753.4005574	0.08
23	23	2	3 Home Garden	1113.24129280	49153.8418755	0.05
24	24	24	4 Agricultural Land	783.91632547100	23770.6046468	0.02
Sho	v All Features 🖕					

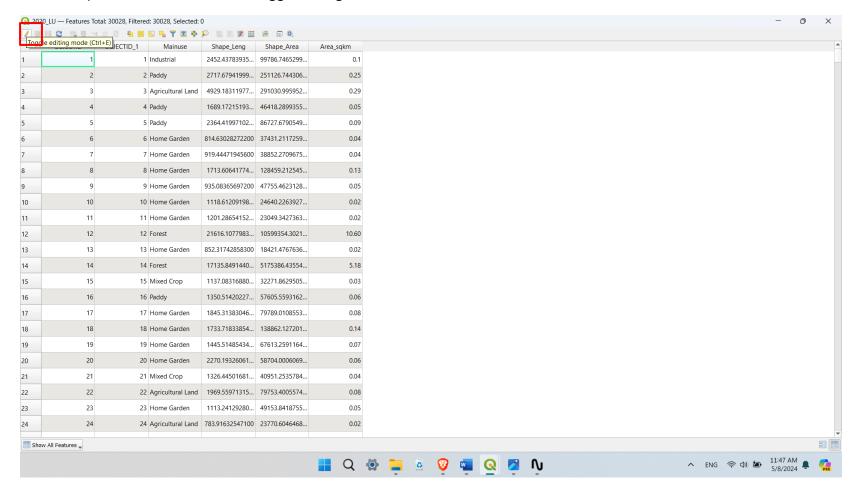
We divide all the above land uses into 4 main categories. They can be shown below.

Agricultural Lands	Built-up Areas	Vegetation	Water Bodies
Agricultural Land	Archeological Sites	Forest	Water Bodies
Chena	Aviation	Grassland	Catchment Area
Coconut	Bank & Allied	Marshy	Dam
Mixed Crop	Commercial/ Residential	Plantation	Abandon Tank
Paddy	Commercial	Other Plantation	River
	Educational	Scrub	Water Tank
	Health		
	Home Garden		
	Industrial		
	Institutional		
	Open Space		
	RDA Road		
	Other Road		
	Railway		
	Religious		
	Reservation		
	Residential		
	Socio-cultural		
	Sports & Amusement		
	Sores & Warehouse		
	Tourism		
	Transportation		
	Under Construction		
	Utility		
	Vacant Building		
	Vacant Land		

Table 3 -Land use categorization for the selected land use layers

4.3 Next, we update these 4 land use categories in the attribute table above. For that, the following steps should be followed.

- First, we should create a new field in the attribute table named "2020".
- Click on the pencil icon and turn on the "Toggle editing mode".

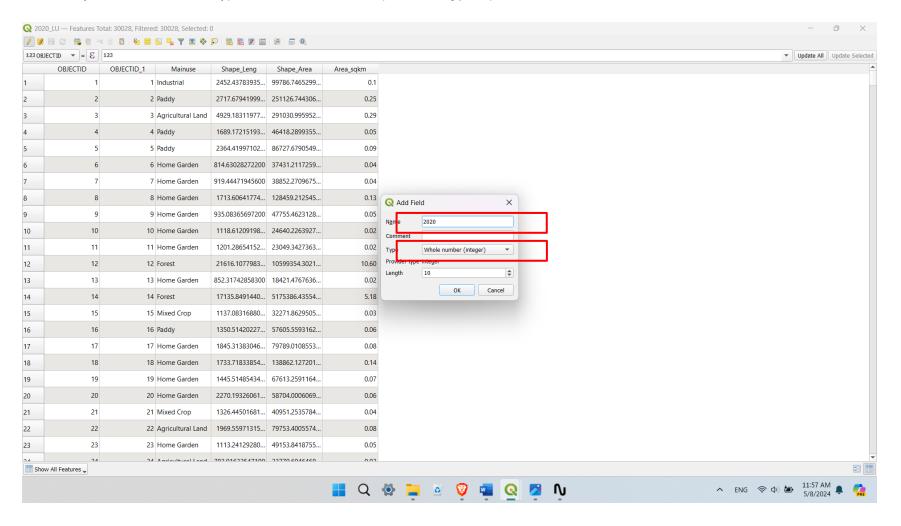


4.4 Now the layer is in editable mode. Then, click on the icon for "**New field**" as follows.

3 OBJECTID	D = E 123		New field (C	trl+W)		Update All U
(OBJECTID OBJECT	ID_1 Mainuse	Shape_Leng	Shape_Area	Area_sqkm	
	1	1 Industrial	2452.43783935	99786.7465299	0.1	
	2	2 Paddy	2717.67941999	251126.744306	0.25	
	3	3 Agricultural Land	4929.18311977	291030.995952	0.29	
	4	4 Paddy	1689.17215193	46418.2899355	0.05	
	5	5 Paddy	2364.41997102	86727.6790549	0.09	
	6	6 Home Garden	814.63028272200	37431.2117259	0.04	
	7	7 Home Garden	919.44471945600	38852.2709675	0.04	
	8	8 Home Garden	1713.60641774	128459.212545	0.13	
	9	9 Home Garden	935.08365697200	47755.4623128	0.05	
	10	10 Home Garden	1118.61209198	24640.2263927	0.02	
	11	11 Home Garden	1201.28654152	23049.3427363	0.02	
2	12	12 Forest	21616.1077983	10599354.3021	10.60	
	13	13 Home Garden	852.31742858300	18421.4767636	0.02	
L .	14	14 Forest	17135.8491440	5175386.43554	5.18	
;	15	15 Mixed Crop	1137.08316880	32271.8629505	0.03	
	16	16 Paddy	1350.51420227	57605.5593162	0.06	
	17	17 Home Garden	1845.31383046	79789.0108553	0.08	
3	18	18 Home Garden	1733.71833854	138862.127201	0.14	
)	19	19 Home Garden	1445.51485434	67613.2591164	0.07	
)	20	20 Home Garden	2270.19326061	58704.0006069	0.06	
	21	21 Mixed Crop	1326.44501681	40951.2535784	0.04	
	22	22 Agricultural Land	1969.55971315	79753.4005574	0.08	
	23	23 Home Garden	1113.24129280	49153.8418755	0.05	
Show All F	24	24 Agricultural Land	702 01622547100	22770 6046460	0.02	

4.5 After clicking on the "New field" icon, the following window will open. Then, enter the Name as "2020".

4.6 Then, you have to select the type of the field. For that, expand the "Type" option here.



4.7 We are going to enter a text in this field. Therefore, the type named "**Text (string)**" should be selected.

OBJEC	CTID 🔻 = E	123						▼ Update All	Update S
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm			
	1		1 Industrial	2452.43783935	99786.7465299	0.1			
	2		2 Paddy	2717.67941999	251126.744306	0.25			
	3		3 Agricultural Land	4929.18311977	291030.995952	0.29			
	4		4 Paddy	1689.17215193	46418.2899355	0.05			
	5		5 Paddy	2364.41997102	86727.6790549	0.09			
	6		6 Home Garden	814.63028272200	37431.2117259	0.04			
	7		7 Home Garden	919.44471945600	38852.2709675	0.04			
	8		8 Home Garden	1713.60641774	128459.212545	0.13	Q Add Field X		
	9		9 Home Garden	935.08365697200	47755.4623128	0.05	Name 2020		
	10	1	0 Home Garden	1118.61209198	24640.2263927	0.02	Comment		
	11	1	1 Home Garden	1201.28654152	23049.3427363	0.02	Type Whole number (integer)		
	12	1	2 Forest	21616.1077983	10599354.3021	10.60	Provider type Whole number (integer 64 bit)		
	13	1	3 Home Garden	852.31742858300	18421.4767636	0.02	Length Decimal number (real) Text (string)		
	14	1	4 Forest	17135.8491440	5175386.43554	5.18	Date		
	15	1	5 Mixed Crop	1137.08316880	32271.8629505	0.03			
	16	1	6 Paddy	1350.51420227	57605.5593162	0.06			
	17	1	7 Home Garden	1845.31383046	79789.0108553	0.08			
	18	1	8 Home Garden	1733.71833854	138862.127201	0.14			
	19	1	9 Home Garden	1445.51485434	67613.2591164	0.07			
,	20	2	0 Home Garden	2270.19326061	58704.0006069	0.06			
	21	2	1 Mixed Crop	1326.44501681	40951.2535784	0.04			
	22	2	2 Agricultural Land	1969.55971315	79753.4005574	0.08			
	23	2	3 Home Garden	1113.24129280	49153.8418755	0.05			
	24	n	A Agricultural Land	702 016226 47100	22770 6046460	0.02			
Show	All Features 🚽								[

4.8 Since I am going to type a word here, I will set the text length as "25". But we can specify the amount we need according to the length of the word or several words we use. After setting all these, click on "**OK**" to proceed.

	▼ = € 123						▼ Update	All Update Se
0		CTID_1 Mainuse	Shape_Leng	Shape_Area	Area_sqkm	1		
	1	1 Industrial		99786.7465299	0.1			
	2	2 Paddy		251126.744306	0.25			
	3	3 Agricultural Land	4929.18311977	291030.995952	0.29)		
	4	4 Paddy	1689.17215193	46418.2899355	0.05	j		
	5	5 Paddy	2364.41997102	86727.6790549	0.09	9		
	6	6 Home Garden	814.63028272200	37431.2117259	0.04	4		
	7	7 Home Garden	919.44471945600	38852.2709675	0.04	4		
	8	8 Home Garden	1713.60641774	128459.212545	0.13	3 🔇 Add Field X		
	9	9 Home Garden	935.08365697200	47755.4623128	0.05	5 Name 2020		
	10	10 Home Garden	1118.61209198	24640.2263927	0.02			
	11	11 Home Garden	1201.28654152	23049.3427363	0.02	2 Type Text (string)		
	12	12 Forest	21616.1077983	10599354.3021	10.60	ength 25 C		
	13	13 Home Garden	852.31742858300	18421.4767636	0.02	2		
	14	14 Forest	17135.8491440	5175386.43554	5.18	8 Cancel		
	15	15 Mixed Crop	1137.08316880	32271.8629505	0.03	3		
	16	16 Paddy	1350.51420227	57605.5593162	0.06	5		
	17	17 Home Garden	1845.31383046	79789.0108553	0.08	3		
3	18	18 Home Garden	1733.71833854	138862.127201	0.14	4		
	19	19 Home Garden	1445.51485434	67613.2591164	0.07	7		
	20	20 Home Garden	2270.19326061	58704.0006069	0.06	5		
	21	21 Mixed Crop	1326.44501681	40951.2535784	0.04	4		
2	22	22 Agricultural Land	1969.55971315	79753.4005574	0.08	3		
;	23	23 Home Garden	1113.24129280	49153.8418755	0.05	5		
Show All Fe	24	24 Apricultural Land	702 01622547100	22770 6046460	0.02			2

4.9 Now, the newly added field will be shown as follows.

3 OBJECT II	3 = × 0	123				
(OBJECTID	OBJECTID_1 Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
	1	1 Industrial	2452.43783935	99786.7465299	0.1	NULL
	2	2 Paddy	2717.67941999	251126.744306	0.25	NULL
_	3	3 Agricultural Lanc	4929.18311977	291030.995952	0.29	NULL
	4	4 Paddy	1689.17215193	46418.2899355	0.05	NULL
	5	5 Paddy	2364.41997102	86727.6790549	0.09	NULL
	6	6 Home Garden	814.63028272200	37431.2117259	0.04	NULL
	7	7 Home Garden	919.44471945600	38852.2709675	0.04	NULL
	8	8 Home Garden	1713.60641774	128459.212545	0.13	NULL
	9	9 Home Garden	935.08365697200	47755.4623128	0.05	NULL
	10	10 Home Garden	1118.61209198	24640.2263927	0.02	NULL
	11	11 Home Garden	1201.28654152	23049.3427363	0.02	NULL
	12	12 Forest	21616.1077983	10599354.3021	10.60	NULL
	13	13 Home Garden	852.31742858300	18421.4767636	0.02	NULL
F	14	14 Forest	17135.8491440	5175386.43554	5.18	NULL
	15	15 Mixed Crop	1 1 37.08316880	32271.8629505	0.03	NULL
	16	16 Paddy	1350.51420227	57605.5593162	0.06	NULL
	17	17 Home Garden	1845.31383046	79789.0108553	0.08	NULL
	18	18 Home Garden	1733.71833854	138862.127201	0.14	NULL
	19	19 Home Garden	1445.51485434	67613.2591164	0.07	NULL
	20	20 Home Garden	2270.19326061	58704.0006069	0.06	NULL
	21	21 Mixed Crop	1326.44501681	40951.2535784	0.04	NULL
	22	22 Agricultural Lanc	1969.55971315	79753.4005574	0.08	NULL
3	23	23 Home Garden	1113.24129280	49153.8418755	0.05	NULL
	74	34 Agricultural Lang	702 01622647100	22770 6046460	0.00	кинт

4.10 Now, we have to add the values into this new field. For that, we should filter each land use from the attribute table, according to our classification.

- 1. Open the "Select by the expression". Then, the following window will open.
- 2. Click on the ">" mark and expand the "Fields and Values". Or you can double-click on the "Fields and Values" to expand it.
- 3. Double-click on "Mainuse".
- 4. Click on "all unique". All the characters under the "Mainuse" will be shown as follows.

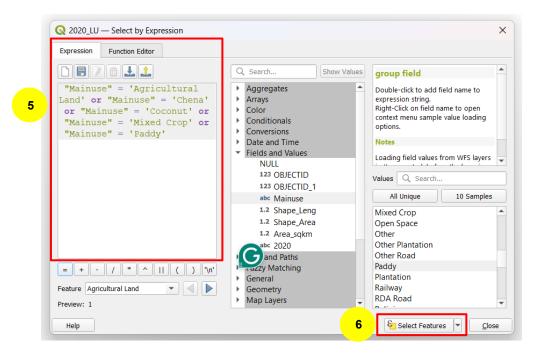
	OBJECTID OBJECTID	1 fainuse	Shape_Leng	Shape_Area	Area_sqkm 2020			
	1	strial	2452.43783935	99786.7465299	0.1 NULL			
	2	2 Paddy	2717.67941999	251126.744306	0.25 NULL			
	3	3 Agricultural Land	4929.18311977	291030.995952	0.29 NULL			
	4	4 Paddy	1689.17215193	46418.2899355	0.05 NULL			
	5	5 Paddy	2364.41997102	86727.6790549	0.09 NULL			
	6	6 Home Garden	814.63028272200	37431.2117259	0.04 NULL	Q 2020_LU — Select by Expression		×
	7	7 Home Garden	919.44471945600	38852.2709675	0.04 NULL	Expression Function Editor		
	8	8 Home Garden	1713.60641774	128459.212545	0.13 NULL		Q Search Show Value	s group field
	9	9 Home Garden	935.08365697200	47755.4623128	0.05 NULL	"Mainuse"	 Aggregates Arrays 	 Double-click to add field name to expression string.
)	10	10 Home Garden	1118.61209198	24640.2263927	0.02 NULL		Color Conditionals	Right-Click on field name to open context menu sample value loading
	11	11 Home Garden	1201.28654152	23049.3427363	0.02 NULL		 Conversions 	options.
2	12	12 Forest	21616.1077983	10599354.3021	10.60 NULL	2	 Date and Time Fields and Values 	Loading field values from WFS layers
3	13	13 Home Garden	852.31742858300	18421.4767636	0.02 NULL		NULL 123 OBJECTID	Values Q Search
1	14	14 Forest	17135.8491440	5175386.43554	5.18 NULL		123 OBJECTID 1 abc Mainuse	All Unique 10 Samples
5	15	15 Mixed Crop	1137.08316880	32271.8629505	0.03 NULL	3	1.2 Shape_Leng	Abondon Tank
;	16	16 Paddy	1350.51420227	57605.5593162	0.06 NULL		1.2 Shape_Area 1.2 Area_sqkm	Agricultural Land Archaeological Places
	17	17 Home Garden	1845.31383046	79789.0108553	0.08 NULL		abc 2020 Files and Paths	Aviation Bank & Allied
3	18	18 Home Garden	1733.71833854	138862.127201	0.14 NULL	= + - / * ^ () "\n"	Fuzzy Matching General	Catchment Area Chena
,	19	19 Home Garden	1445.51485434	67613.2591164	0.07 NULL	Feature Agricultural Land	Geometry	Coconut Com/Resi
)	20	20 Home Garden	2270.19326061	58704.0006069	0.06 NULL	Preview: 'Agricultural Land'	Map Layers	▼ Com/Resi
1	21	21 Mixed Crop	1326.44501681	40951.2535784	0.04 NULL	Help		Select Features V
2	22	22 Agricultural Land	1969.55971315	79753.4005574	0.08 NULL			
3	23	23 Home Garden	1113.24129280	49153.8418755	0.05 NULL			
	24	24 Apricultural Land	702.01622547100	22770 6046460				

5. Then, you have to enter the following expression on the expression tab. For that, double-click on "Mainuse", type "=", and double-click on the relevant land use category according to our classification.

According to the above steps, first, select the land uses under the category "Agricultural Lands". Once done entering a land use using this ["Mainuse" = 'Agricultural Land'], type "or" and follow the same steps to add other land use categories into the expression. The "or" operator is used here to create a logical condition that selects features based on multiple criteria.

• So, add each land use continuously in this way,

"Mainuse" = 'Agricultural Land' or "Mainuse" = 'Chena' or "Mainuse" = 'Coconut' or "Mainuse" = 'Mixed Crop' or "Mainuse" = 'Paddy'



After entering all land use categories into the expression using the above way, click on "Select Features".

The selected data will be shown as follows in the blue color.

ECLID	3 = *	123						▼ Up
C	BJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	
	1		Industrial	2452.43783935	99786.7465299	0.1	NULL	
			2 Paddy	2717.67941999	251126.744306	0.25	NULL	
			B Agricultural Land	4929.18311977	291030.995952	0.29	NULL	
			1 Paddy	1689.17215193	46418.2899355	0.05	NULL	
	5	:	5 Paddy	2364.41997102	86727.6790549	0.09	NULL	
	6	(5 Home Garden	814.63028272200	37431.2117259	0.04	NULL	
	7	-	7 Home Garden	919.44471945600	38852.2709675	0.04	NULL	
	8	8	B Home Garden	1713.60641774	128459.212545	0.13	NULL	
	9	9	Home Garden	935.08365697200	47755.4623128	0.05	NULL	
	10	10) Home Garden	1118.61209198	24640.2263927	0.02	NULL	
	11	1	Home Garden	1201.28654152	23049.3427363	0.02	NULL	
	12	12	2 Forest	21616.1077983	10599354.3021	10.60	NULL	
	13	1	B Home Garden	852.31742858300	18421.4767636	0.02	NULL	
	14	14	Forest	17135.8491440	5175386.43554	5.18	NULL	
	15		Mixed Crop	1137.08316880	32271.8629505	0.03	NULL	
	16	10	5 Paddy	1350.51420227	57605.5593162	0.06	NULL	
	17	17	7 Home Garden	1845.31383046	79789.0108553	0.08	NULL	
	18	18	B Home Garden	1733.71833854	138862.127201	0.14	NULL	
	19	19	Home Garden	1445.51485434	67613.2591164	0.07	NULL	
	20	20) Home Garden	2270.19326061	58704.0006069	0.06	NULL	
	21		Mixed Crop	1326.44501681	40951.2535784	0.04	NULL	
	22	22	2 Agricultural Land	1969.55971315	79753.4005574	0.08	NULL	
	23	23	B Home Garden	1113.24129280	49153.8418755	0.05	NULL	
	eatures 🚽	2	Agricultural Land	702 01622547100	22770 6046460	0.02	NILII I	

4.11 In the next step, we have to add the text for the "**2020**" column. According to the above steps, we selected here the land use categories for the category "Agricultural Lands". For that, click on the icon for "**Open field calculator**".

OBJECTID	• = E 1	23		Ľ	open neld calculate		
C	BJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
	1		Industrial		99786.7465299		NULL
			Paddy	2717.67941999	251126.744306		NULL
			Agricultural Land	4929.18311977	291030.995952		NULL
	4		Paddy	1689.17215193	46418.2899355		NULL
	5		Paddy	2364.41997102	86727.6790549		NULL
	6		Home Garden	814.63028272200			NULL
	7		Home Garden	919.44471945600			NULL
	8		Home Garden		128459.212545		NULL
	9		Home Garden	935.08365697200			NULL
	10		Home Garden		24640.2263927		NULL
	11		Home Garden		23049.3427363		NULL
	12		Forest Home Garden	852.31742858300	10599354.3021		NULL
_	13		Forest		5175386.43554		NULL
	14		Mixed Crop	1137.08316880	32271.8629505		NULL
			Paddy		57605.5593162		NULL
	17		Home Garden		79789.0108553		NULL
	18		Home Garden		138862.127201		NULL
	19		Home Garden		67613.2591164		NULL
	20		Home Garden		58704.0006069		NULL
	21		Mixed Crop	1326.44501681	40951.2535784		NULL
			Agricultural Land		79753.4005574		NULL
	23		Home Garden		49153.8418755		NULL
	24	24	Agricultural Land	702 016225 47100			NII II I

4.12 The field calculator will open. Click on the "**Update existing field**" and make sure to display the "✓" mark on that. Through this, an existing field in the attribute table will be updated.

Q 202	0_LU — Features T	otal: 30028, Filtered: 30028, Selected: 7	7253			- 0 ×
1	🕞 🗇 📑 👼 🍝	< 🖻 🖻 i 🗞 🗮 💟 🔩 🍸 🔳 🐥 .	P 🖪 🖪 🗶 🖽	i i i i i i i i i i i i i i i i i i i	2	
123 OB	JECTID ▼ = E					Update All Update Selected
	OBJECTID	OBJECTID_1 Mainuse	Shape_Leng	Shape_A		
1	1	1 Industrial		99786.7465		
2	2	2 Paddy	2717.67941999	251126.74	2020_LU — Field Calculator X	
3	3	3 Agricultural Land	4929.18311977	291030.9		
4	4	4 Paddy	1689.17215193	46418.28	✓ Only update 7253 selected features Create a new field ✓ Update prioring field	
5	5	5 Paddy	2364.41997102	86727.67	Create virtual field	
6	6	6 Home Garden	814.63028272200	37431.21	Output field name	
7	7	7 Home Garden	919.44471945600	38852.27	Output field type Whole number (integer)	
8	8	8 Home Garden	1713.60641774	128459.2	Output field length 10 Precision 3	
9	9	9 Home Garden	935.08365697200	47755.46	Expression Function Editor	
10	10	10 Home Garden	1118.61209198	24640.22		
11	11	11 Home Garden	1201.28654152	23049.34	row_number≜ → Aggregates	
12	12	12 Forest	21616.1077983	10599354	Arrays Color	
13	13	13 Home Garden	852.31742858300	18421.47	Conditionals Conversions	
14	14	14 Forest	17135.8491440	5175386.	 Date and Ti Fields and V. 	
15	15	15 Mixed Crop	1137.08316880	32271.86	Files and Pat.	
16	16	16 Paddy	1350.51420227	57605.55		
17	17	17 Home Garden	1845.31383046	79789.01	Feature ultural Land V Geometry	
18	18	18 Home Garden	1733.71833854	138862.1		
19	19	19 Home Garden	1445.51485434	67613.25	OK Cancel Help	
20	20	20 Home Garden	2270.19326061	58704.000		
21	21	21 Mixed Crop	1326.44501681	40951.2535	5784 0.04 NULL	
22	22	22 Agricultural Land	1969.55971315	79753.4005	5574 0.08 NULL	
23	23	23 Home Garden	1113.24129280	49153.8418	0.05 NULL	
Sho	w All Features	24 Agricultural Land	702 01622547100	22770 6049		▼ ()
0110	w , a reduies v					
						ヘ ENG 奈 d× 🗈 5:07 PM 🌲 🧖

4.13 Now, we have to select the existing field that we want to update.

Q 2020_LU — Field Calculator	×	Q 2020_LU — Field Calculator	×
✓ Only update 7253 selected features		✓ Only update 7253 selected features	
Create a new field	✓ Update existing field	Create a new field	✓ Update existing field
Create virtual field		Create virtual field	
Output field name		Output field name	123 OBJECTID
Output field type Whole number (intege	er) 👻	Output field type Whole number (integer)	123 OBJECTID_1
Output field length 10 🜩 Precision	3	Output field length 10 🗣 Precision 3	abc Mainuse
Expression Function Editor		Expression Function Editor	1.2 Shape_Leng
			1.2 Shape_Area Shu 1.2 Area sokm
	Q Show Help		
	row_numbet≜ ▶ Aggregates		ow_nu n all 2020 Aggrega <geometry></geometry>
	Arrays	► A	arrays
	Color Conditionals		color Conditionals
	Conversions		Conversions
	Date and Ti		Date and Ti
	Fields and V. Files and Pat.		ields and V. — iles and Pat.
= + - / * ^ () '\n'	Fuzzy Match.		uzzy Match.
	General Geometry		General Geometry
Feature ultural Land 💌 🔍 🕨	Map Lavers		Nap Lavers 💌
Preview:		Preview:	
	OK Cancel Help		OK Cancel Help

• For that, click on this expandable tab.

• Then select "**2020**".

After selecting the field, you can use the following expression to add "Agricultural Lands" to the selected field at once. Then the newly added field of all the land uses we selected above will be updated as "Agricultural Lands" on the attribute table.

• Once done entering this expression, you can click on "OK" to proceed. This expression contains,

Concat ("Name of the existing field", 'The value')

• You should correctly type this expression using single commas and double commas. If you do not enter this correctly, you will have an error message.

• The expression,

Concat ("2020", 'Agricultural Lands')

- lf
- **Double Quotes (" "):** Used for field names to reference the data in those fields.

Create a new field	✓ Update existing field
Create virtual field Uutput field name Uutput field type Whole number (integer Uutput field length 10 Precision	 ▼ ↓
Expression Function Editor	Conversions
Feature ultural Lands'	 Date and Ti Fields and V. Files and Pat. Fuzzy Match. General Geometry Map Lavers

deselect all the selected features, you can use the below tool.

• Now, the values are added to the attribute table.

123 OB	JECTID 💌 = E	123					
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
1	1	1	Industrial	2452.43783935	99786.7465299		1 NULL
2		2	Paddy	2717.67941999	251126.744306	0.2	5 Agricultural Lar
3		3	Agricultural Land	4929.18311977	291030.995952	0.2	9 Agricultural Lar
4		4	Paddy	1689.17215193	46418.2899355	0.0	5 Agricultural Lar
5	5	5	Paddy	2364.41997102	86727.6790549	0.0	9 Agricultural Lar
6	6	6	Home Garden	814.63028272200	37431.2117259	0.0	4 NULL
7	7	7	Home Garden	919.44471945600	38852.2709675	0.0	4 NULL
8	8	8	Home Garden	1713.60641774	128459.212545	0.1	3 NULL
9	9	9	Home Garden	935.08365697200	47755.4623128	0.0	5 NULL
10	10	10	Home Garden	1118.61209198	24640.2263927	0.0	2 NULL
11	11	11	Home Garden	1201.28654152	23049.3427363	0.0	2 NULL
12	12	12	Forest	21616.1077983	10599354.3021	10.5	0 NULL
13	13	13	Home Garden	852.31742858300	18421.4767636	0.0	2 NULL
14	14	14	Forest	17135.8491440	5175386.43554	5.1	8 NULL
15	15	15	Mixed Crop	1137.08316880	32271.8629505	0.0	3 Agricultural Lar
16		16	Paddy	1350.51420227	57605.5593162	C.O	6 Agricultural Lar
17	17	17	Home Garden	1845.31383046	79789.0108553	0.0	8 NULL
18	18	18	Home Garden	1733.71833854	138862.127201	0.1	4 NULL
19	19	19	Home Garden	1445.51485434	67613.2591164	0.0	7 NULL
20	20	20	Home Garden	2270.19326061	58704.0006069	0.0	6 NULL
21	21	21	Mixed Crop	1326.44501681	40951.2535784	0.0	4 Agricultural Lar
22		22	Agricultural Land	1969.55971315	79753.4005574	0.0	8 Agricultural Lar
23	23	23	Home Garden	1113.24129280	49153.8418755	0.0	5 NULL

	TID ▼ = E I	123	Deselect all f	features from the la	yer (Ctrl+Shift+A)		
_	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
	1	1	1 Industrial	2452.43783935	99786.7465299	0.1	NULL
			2 Paddy	2717.67941999	251126.744306	0.25	Agricultural Lands
	3		3 Agricultural Land	4929.18311977	291030.995952	0.29	Agricultural Lands
t i		4	4 Paddy	1689.17215193	46418.2899355	0.05	Agricultural Lands
5	5		5 Paddy	2364.41997102	86727.6790549	0.09	Agricultural Lands
5	6	e	6 Home Garden	814.63028272200	37431.2117259	0.04	NULL
,	7	7	7 Home Garden	919.44471945600	38852.2709675	0.04	NULL
3	8	٤	8 Home Garden	1713.60641774	128459.212545	0.13	NULL
)	9	ç	9 Home Garden	935.08365697200	47755.4623128	0.05	NULL
10	10	1(0 Home Garden	1118.61209198	24640.2263927	0.02	NULL
11	11	11	1 Home Garden	1201.28654152	23049.3427363	0.02	NULL
12	12	17	2 Forest	21616.1077983	10599354.3021	10.60	NULL
13	13	19	3 Home Garden	852.31742858300	18421.4767636	0.02	NULL
14	14	14	4 Forest	17135.8491440	5175386.43554	5.18	NULL
15	15		5 Mixed Crop	1137.08316880	32271.8629505		Agricultural Lands
16	16		6 Paddy		57605.5593162		Agricultural Lands
17	17		7 Home Garden		79789.0108553		NULL
18	18		8 Home Garden		138862.127201		NULL
19	19		9 Home Garden		67613.2591164		NULL
20	20		0 Home Garden		58704.0006069		NULL
	20		1 Mixed Crop	1326.44501681	40951.2535784		Agricultural Lands
21							
22	22		2 Agricultural Land		79753.4005574		Agricultural Lands
23	23		3 Home Garden	1113.24129280		0.05	NULL
Show A	Il Features	. <u> </u>	Agricultural Land	702 01622547100	00770 6046460	0.03	Agricultural Lands

By following the same steps as above, the attribute table should also be updated for the main land use categories that we have selected namely **built-up areas**, **vegetation**, and **water bodies**. (As shown in Table 3) Once this "2020" field in the attribute table is completely prepared, it will look like this.

—	O	×	

	CTID = E					
	OBJECTID	OBJECTID_1 Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020
	1	1 Industrial	2452.43783935	99786.7465299	0.1	Builtup
2	2	2 Paddy	2717.67941999	251126.744306	0.25	Agricultural Lands
3	3	3 Agricultural Land	4929.18311977	291030.995952	0.29	Agricultural Lands
t I	4	4 Paddy	1689.17215193	46418.2899355	0.05	Agricultural Lands
5	5	5 Paddy	2364.41997102	86727.6790549	0.09	Agricultural Lands
5	6	6 Home Garden	814.63028272200	37431.2117259	0.04	Builtup
,	7	7 Home Garden	919.44471945600	38852.2709675	0.04	Builtup
3	8	8 Home Garden	1713.60641774	128459.212545	0.13	Builtup
)	9	9 Home Garden	935.08365697200	47755.4623128	0.05	Builtup
10	10	10 Home Garden	1118.61209198	24640.2263927	0.02	Builtup
1	11	11 Home Garden	1201.28654152	23049.3427363	0.02	Builtup
2	12	12 Forest	21616.1077983	10599354.3021	10.60	Vegetation
13	13	13 Home Garden	852.31742858300	18421.4767636	0.02	Builtup
4	14	14 Forest	17135.8491440	5175386.43554	5.18	Vegetation
15	15	15 Mixed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands
16	16	16 Paddy	1350.51420227	57605.5593162		Agricultural Lands
17	17	17 Home Garden		79789.0108553		Builtup
18	18	18 Home Garden		138862.127201		Builtup
19	19	19 Home Garden		67613.2591164		Builtup
20	20	20 Home Garden		58704.0006069		Builtup
21	21	21 Mixed Crop		40951.2535784		Agricultural Lands
22	22	22 Agricultural Land				Agricultural Lands
23	23	23 Home Garden		49153.8418755		Builtup
.5	23	23 Nonie Garden				Agricultural Lands
🛅 Shov	All Features 🖕					

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4.14 After adding these data successfully, click on the pencil icon again and **save** the edits.

	OBJECTID	123 OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020							▼ Update All
	1	OBLCHD_I	1 Industrial		99786.7465299		Builtup							
	2		2 Paddy		251126.744306		Agricultural Lands							
_	3		3 Agricultural Land		291030.995952		Agricultural Lands							
	4		4 Paddy		46418.2899355		Agricultural Lands							
	5		5 Paddy		86727.6790549		Agricultural Lands							
_	6		6 Home Garden	814.63028272200			Builtup							
_	7		7 Home Garden	919.44471945600			Builtup							
	8		8 Home Garden	1713.60641774	128459.212545	0.13	Builtup							
	9		9 Home Garden	935.08365697200	47755.4623128	O Sto	p Editing		×					
)	10	1	10 Home Garden	1118.61209198	24640.2263927		-							
1	11	1	11 Home Garden	1201.28654152	23049.3427363	?	Do you want to save th	e changes to layer 2020_I	LU?					
2	12	i	12 Forest	21616.1077983	10599354.3021		Save	Discard Cance						
3	13	1	13 Home Garden	852.31742858300	18421.4767636	0.02	Builtup							
1	14	1	14 Forest	17135.8491440	5175386.43554	5.18	/egetation							
	15	1	15 Mixed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands							
	16	1	16 Paddy	1350.51420227	57605.5593162	0.06	Agricultural Lands							
	17	i	17 Home Garden	1845.31383046	79789.0108553	0.08	Builtup							
	18	1	18 Home Garden	1733.71833854	138862.127201	0.14	Builtup							
	19	ſ	19 Home Garden	1445.51485434	67613.2591164	0.07	Builtup							
	20	2	20 Home Garden	2270.19326061	58704.0006069	0.06	Builtup							
	21	ź	21 Mixed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands							
2	22	ž	22 Agricultural Land	1969.55971315	79753.4005574	0.08	Agricultural Lands							
;	23	â	23 Home Garden	1113.24129280	49153.8418755	0.05	Builtup							
	24		14 Agricultural Land	702 01622547100	22770 6046460	0.02	Anicultural Lands							

Step 05 - Rasterization of the layers

When we convert a vector layer to a raster layer in QGIS, the choice of field for rasterization is crucial for accurate representation. The selected field determines the values assigned to each raster cell, influencing the interpretation of the resulting raster layer. It's essential to note that string-type fields, containing text or categorical labels, cannot be selected for rasterization. This limitation arises because rasterization requires numeric values to represent information in raster cells effectively. Numeric attributes, such as integer fields for categorical data and floating-point or double fields for continuous or decimal data, are suitable choices for rasterization.

For categorical data, such as land use categories, an integer field with class codes (e.g., 1 for urban, 2 for forest) is ideal. Conversely, continuous data, like elevation, is best represented using a floating-point field with actual elevation values. When converting vector layers with string fields, it's advisable to create new numeric fields, perhaps using the Field Calculator tool, to store relevant quantitative information before rasterization. By selecting the appropriate field type, we can ensure the meaningful interpretation of the resulting raster layer, facilitating accurate analysis and visualization of spatial data.

Accordingly, by adding another field in the same attribute table that we prepared, we should give a numeric value for the 4 main land use categories. Let's give numerical values for land uses as follows.

Land Use Category	Numeric Value
Built-up Areas	1
Agricultural Lands	2
Vegetation	3
Water Bodies	4

Table 4 — Numerical values for the land use categories

5.1 Turn on the editable mode of the layer by clicking the "**Toggle editing mode**" tool. Then, add a new field as before. Name it as "LU" and set the type as a numeric type. I set here the type "Whole number (integer)" and the length as "10".

		: 💿 🖸 🗞 🚍 💟 🔩 🍸 🗮 🍕					▼ Update All Update Se
	BJECTID	OBJECTID_1 Mainuse	Sh 2	Shape_Area	Area_sqkm	2020	opute vir opute se
	1	1 Industrial	2452.45 .5	99786.7465299		Builtup	
	2	2 Paddy	2717.67941999	251126.744306	0.25	Agricultural Lands	
	3	3 Agricultural Lan	4929.18311977	291030.995952	0.29	Agricultural Lands	
	4	4 Paddy	1689.17215193	46418.2899355	0.05	Agricultural Lands	
	5	5 Paddy	2364.41997102	86727.6790549	0.09	Agricultural Lands	
	6	6 Home Garden	814.63028272200	37431.2117259	0.04	Builtup	
	7	7 Home Garden	919.44471945600	38852.2709675	0.04	Builtup	
	8	8 Home Garden	1713.60641774	128459.212545	0.13	Add Field X	
	9	9 Home Garden	935.08365697200	47755.4623128	0.05		
	10	10 Home Garden	1118.61209198	24640.2263927	0.02	Name LU	
	11	11 Home Garden	1201.28654152	23049.3427363	0.02	Trpe Whole number (integer)	
	12	12 Forest	21616.1077983	10599354.3021	10.60	Plovider type integer	
	13	13 Home Garden	852.31742858300	18421.4767636	0.02	Lingth 10 🗢	
	14	14 Forest	17135.8491440	5175386.43554	5.18	OK Cancel	
	15	15 Mixed Crop	1137.08316880	32271.8629505	0.03	Agneultural Lands	
	16	16 Paddy	1350.51420227	57605.5593162	0.06	Agricultural Lands	
	17	17 Home Garden	1845.31383046	79789.0108553	0.08	Builtup	
	18	18 Home Garden	1733.71833854	138862.127201	0.14	Builtup	
	19	19 Home Garden	1445.51485434	67613.2591164	0.07	Builtup	
	20	20 Home Garden	2270.19326061	58704.0006069	0.06	Builtup	
	21	21 Mixed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands	
	22	22 Agricultural Lan	1969.55971315	79753.4005574	0.08	Agricultural Lands	
	23	23 Home Garden	1113.24129280	49153.8418755	0.05	Builtup	
	24	24 Agricultural Las	702.01622547100	22770 6046460	0.00	Apricultural Lands	
w All F	eatures 👻						(

5.2 The newly added field will be shown as follows.

	3 = • 0IT3	123							▼ Update All
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU	
	1	1 Indu	ustrial	2452.43783935	99786.7465299	0.1	Builtup	NULL	
	2	2 Pad	ldy	2717.67941999	251126.744306	0.25	Agricultural Lands	NULL	
	3	3 Agr	ricultural Land	4929.18311977	291030.995952	0.29 /	Agricultural Lands	NULL	
	4	4 Pad	ldy	1689.17215193	46418.2899355	0.05 /	Agricultural Lands	NULL	
	5	5 Pad	ldy	2364.41997102	86727.6790549	0.09	Agricultural Lands	NULL	
	6	6 Hor	me Garden	814.63028272200	37431.2117259	0.04	Builtup	NULL	
	7	7 Hor	me Garden	919.44471945600	38852.2709675	0.04	Builtup	NULL	
	8	8 Hor	me Garden	1713.60641774	128459.212545	0.13	Builtup	NULL	
	9	9 Hor	me Garden	935.08365697200	47755.4623128	0.05	Builtup	NULL	
0	10	10 Hor	me Garden	1118.61209198	24640.2263927	0.02	Builtup	NULL	
1	11	11 Hor	me Garden	1201.28654152	23049.3427363	0.02	Builtup	NULL	
2	12	12 Fore	est	21616.1077983	10599354.3021	10.60	Vegetation	NULL	
3	13	13 Hor	me Garden	852.31742858300	18421.4767636	0.02	Builtup	NULL	
4	14	14 Fore	est	17135.8491440	5175386.43554	5.18	Vegetation	NULL	
5	15	15 Mix	ed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands	NULL	
5	16	16 Pad	ldy	1350.51420227	57605.5593162	0.06	Agricultural Lands	NULL	
7	17	17 Hor	me Garden	1845.31383046	79789.0108553	0.08	Builtup	NULL	
8	18	18 Hor	me Garden	1733.71833854	138862.127201	0.14	Builtup	NULL	
9	19	19 Hor	me Garden	1445.51485434	67613.2591164	0.07	Builtup	NULL	
0	20	20 Hor	me Garden	2270.19326061	58704.0006069	0.06 I	Builtup	NULL	
1	21	21 Mix	ed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands	NULL	
2	22	22 Agr	ricultural Land	1969.55971315	79753.4005574		Agricultural Lands	NULL	
3	23	-	me Garden		49153.8418755		Builtup	NULL	
	24	24 Acr	icultural Land	702 016226 47100	22770 6046460	0.02	Agricultural Lands	<u>ки и г</u>	

5.3 Open the "Select by Expression" and expand the "Fields and Values". Then, double-click on "2020" and type "=". After that, click on "All Unique" and double-click on a land use category. Then the expression will be entered as follows. Finally, click on "Select Features".

С	BJECTID	ID_1 Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU		
		1 Industrial	2452.43783935	99786.7465299	0.1	Builtup	NULL		
	2	2 Paddy	2717.67941999	251126.744306	0.25	Agricultural Lands	NULL		
	3	3 Agricultural Land	4929.18311977	291030.995952	0.29	Agricultural Lands	NULL		
	4	4 Paddy	1689.17215193	46418.2899355	0.05	Agricultural Lands	NULL		
	5	5 Paddy	2364.41997102	86727.6790549	0.09	Agricultural Lands	Q 2020_LU — Select by Expression		×
	6	6 Home Garden	814.63028272200	37431.2117259	0.04	Builtup	Expression Function Editor		
		7 Home Garden	919.44471945600	38852.2709675	0.04	Builtup		Q Search Show Values	group field
	8	8 Home Garden	1713.60641774	128459.212545	0.13	Builtup	"2020" = 'Builtup'	Aggregates	Double-click to add field name to expression string.
	9	9 Home Garden	935.08365697200	47755.4623128	0.05	Builtup	;	 Arrays Color 	expression string. Right-Click on field name to open context menu sample value loading
	10	10 Home Garden	1118.61209198	24640.2263927	0.02	Builtup		ConditionalsConversions	options.
	11	11 Home Garden	1201.28654152	23049.3427363	0.02	Builtup	2	 Date and Time Fields and Values 	Loading rom WFS layers
	12	12 Forest	21616.1077983	10599354.3021	10.60	Vegetation		123 OBJECTID	Values
	13	13 Home Garden	852.31742858300	18421.4767636	0.02	Builtup		123 OBJECTID_1 abc Mainuse	All Unique 10 Samples
	14	14 Forest	17135.8491440	5175386.43554	5.18	Vegetation		1.2 Shape_Leng	Agricultural Lands
	15	15 Mixed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands		1.2 Shape_Area	Builtup Vegetation
	16	16 Paddy	1350.51420227	57605.5593162	0.06	Agricultura Gis	3	abc 2020	Water
	17	17 Home Garden	1845.31383046	79789.0108553	0.08	Builtup	=+-/*^II()"\n'	 Files and Paths 	
	18	18 Home Garden	1733.71833854	138862.127201	0.14	Builtup	Feature Agricultural Land	 Fuzzy Matching General 	
	19	19 Home Garden	1445.51485434	67613.2591164	0.07	Builtup	Preview: 0	 Geometry 	
	20	20 Home Garden	2270.19326061	58704.0006069	0.06	Builtup	Help		Select Features Close
	21	21 Mixed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands	NULL		
	22	22 Agricultural Land	1969.55971315	79753.4005574	0.08	Agricultural Lands	NULL		6
	23	23 Home Garden	1113.24129280	49153.8418755	0.05	Builtup	NULL		
	eatures _	24 Agricultural Land	702 01622647100	22770 6046460	0.02	Agricultural Lands	NIL IL I		

5.4 The selected features are displayed in blue color. Now, open the "Field Calculator" and update the existing field "LU", according to the numerical values that we introduced under Table 4. Use the expression as concat ("LU", '1') for the built-up areas. According to the Table 4, change the numeric value in this expression.

JECI	3 = • CIT							▼ Update All Update
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	1 rea	Area_sqkm	2020	LU
	1		1 Industrial	2452.43783935	.65299		Builtup	NULL
	2		2 Paddy	2717.67941999			Agricultural Lands	NULL
	3		3 Agricultural Land				Agricultural Lands	Q 2020_LU — Field Calculator
	4		4 Paddy	1689.17215193			Agricultural Lands	Only update 18028 selected features
	5		5 Paddy	2364.41997102			Agricultural Lands	Create a new field
				814.63028272200			Builtup	Create virtual field
			7 Home Garden	919.44471945600			Builtup	Output field name Output field name Utput field type Whole number (integer) Utput field type Whole number (integer)
			8 Home Garden	1713.60641774	128459.212545		Builtup	Output field length 10 \Rightarrow Precision 3 \Rightarrow
			9 Home Garden	935.08365697200			Builtup	Expression Function Editor
			0 Home Garden	1118.61209198	24640.2263927		Builtup	C R C Show Help
	11		1 Home Garden	1201.28654152			Builtup	concat ("LU", '1') row_numbe
	12		2 Forest	21616.1077983			Vegetation	► Aggregates ► Arrays
	13	1	3 Home Garden	852.31742858300	18421.4767636	0.02	Builtup	Color Conditionals
	14	14	4 Forest	17135.8491440	5175386.43554		Vegetation	4 Conversions Date and Ti
	15	1	5 Mixed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands	 Fields and V. Files and Pat.
	16	10	6 Paddy	1350.51420227	57605.5593162		Agricultural Lands	► Fuzzy Match.
			7 Home Garden	1845.31383046	79789.0108553	0.08	Builtup	
	18		8 Home Garden	1733.71833854	138862.127201	0.14	Builtup	Feature ultural Land V V Map Layers
			9 Home Garden	1445.51485434	67613.2591164	0.07	Builtup	Preview: '1'
	20	20	0 Home Garden	2270.19326061	58704.0006069	0.06	Builtup	
	21	2	1 Mixed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands	OK Cancel Help
	22	23	2 Agricultural Land	1969.55971315	79753.4005574	0.08	Agricultural Lands	NULL
			3 Home Garden	1113.24129280	49153.8418755	0.05	Builtup	NULL

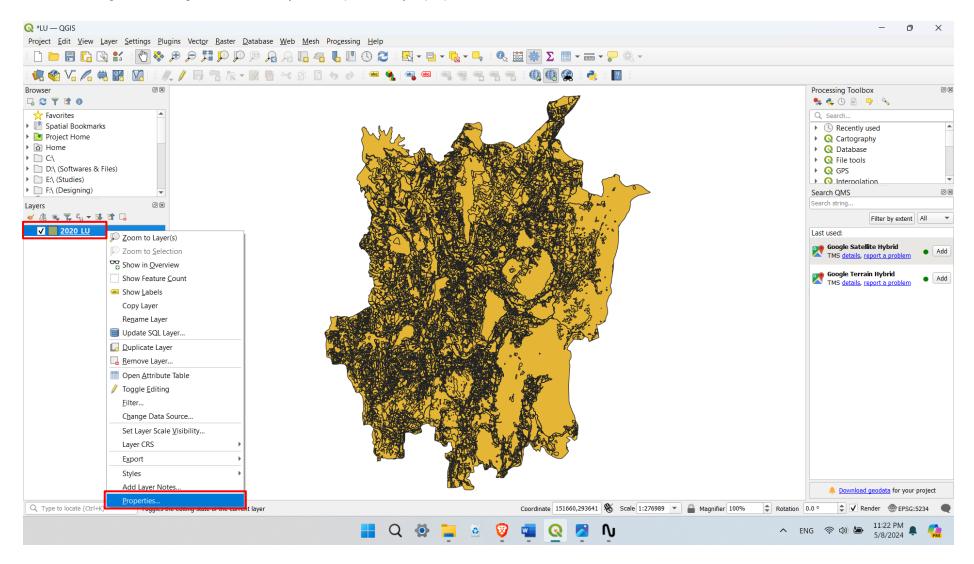
Numeric values are added to this field as follows.

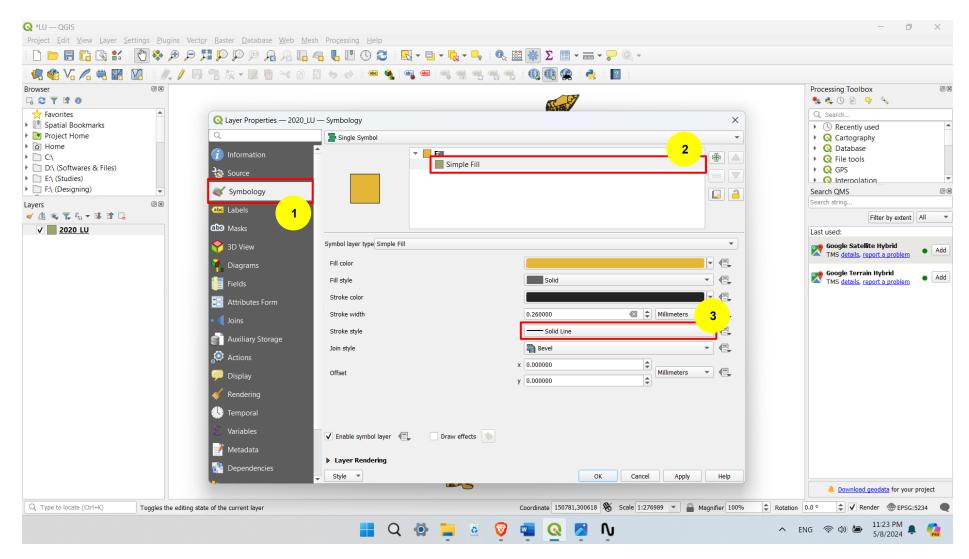
OBJE	ECTID = E	123							▼ Update All Update :
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU	
	1		Industrial	2452.43783935	99786.7465299	0.1	Builtup	1	
	2	â	2 Paddy	2717.67941999	251126.744306	0.25	Agricultural Lands	NULL	
	3	:	3 Agricultural Land	4929.18311977	291030.995952	0.29	Agricultural Lands	NULL	
	4	4	1 Paddy	1689.17215193	46418.2899355	0.05	Agricultural Lands	NULL	
	5		5 Paddy	2364.41997102	86727.6790549	0.09	Agricultural Lands	NULL	
			5 Home Garden	814.63028272200	37431.2117259	0.04	Builtup	1	
			7 Home Garden	919.44471945600	38852.2709675	0.04	Builtup	1	
	8		B Home Garden	1713.60641774	128459.212545	0.13	Builtup	1	
	9		Home Garden	935.08365697200	47755.4623128	0.05	Builtup	1	
	10	1() Home Garden	1118.61209198	24640.2263927	0.02	Builtup	1	
	11		Home Garden	1201.28654152	23049.3427363	0.02	Builtup	1	
	12	12	2 Forest	21616.1077983	10599354.3021	10.60	Vegetation	NULL	
	13	18	B Home Garden	852.31742858300	18421.4767636	0.02	Builtup	1	
	14	14	Forest	17135.8491440	5175386.43554	5.18	Vegetation	NULL	
	15	1	5 Mixed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands	NULL	
	16	10	5 Paddy	1350.51420227	57605.5593162	0.06	Agricultural Lands	NULL	
	17	13	7 Home Garden	1845.31383046	79789.0108553	0.08	Builtup	1	
	18		B Home Garden	1733.71833854	138862.127201	0.14	Builtup	1	
	19		Home Garden	1445.51485434	67613.2591164	0.07	Builtup	1	
	20	20) Home Garden	2270.19326061	58704.0006069	0.06	Builtup	1	
ľ	21	2	Mixed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands	NULL	
	22	22	2 Agricultural Land	1969.55971315	79753.4005574	0.08	Agricultural Lands	NULL	
	23		B Home Garden		49153.8418755		Builtup	1	
	24		Agricultural Land				Agricultural Lands	KILILI.	
Show	/ All Features 🖕						•		

5.5 Then, follow the same steps and add values for other land use categories as well. As the final step, save the edits.

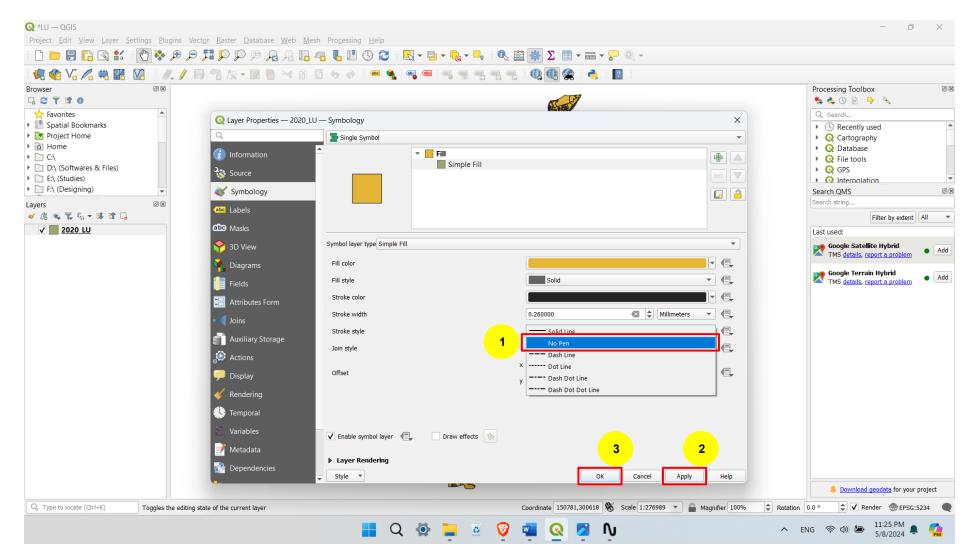
	OBJECTID	OBJECTID_1	Mainuse	Shape_Leng	Shape_Area	Area_sqkm	2020	LU
1	1		1 Industrial	2452.43783935	99786.7465299	0.1	Builtup	1
2	2		2 Paddy	2717.67941999	251126.744306	0.25	Agricultural Lands	2
3	3		3 Agricultural Land	4929.18311977	291030.995952	0.29	Agricultural Lands	2
4	4		4 Paddy	1689.17215193	46418.2899355	0.05	Agricultural Lands	2
5	5		5 Paddy	2364.41997102	86727.6790549	0.09	Agricultural Lands	2
6	6		6 Home Garden	814.63028272200	37431.2117259	0.04	Builtup	1
7	7		7 Home Garden	919.44471945600	38852.2709675	0.04	Builtup	1
8	8		8 Home Garden	1713.60641774	128459.212545	0.13	Builtup	1
9	9		9 Home Garden	935.08365697200	47755.4623128	0.05	Builtup	1
10	10		10 Home Garden	1118.61209198	24640.2263927	0.02	Builtup	1
11	11		11 Home Garden	1201.28654152	23049.3427363	0.02	Builtup	1
12	12		12 Forest	21616.1077983	10599354.3021	10.60	Vegetation	3
13	13		13 Home Garden	852.31742858300	18421.4767636	0.02	Builtup	1
14	14		14 Forest	17135.8491440	5175386.43554	5.18	Vegetation	3
15	15		15 Mixed Crop	1137.08316880	32271.8629505	0.03	Agricultural Lands	2
16	16		16 Paddy	1350.51420227	57605.5593162	0.06	Agricultural Lands	2
17	17		17 Home Garden	1845.31383046	79789.0108553	0.08	Builtup	1
18	18		18 Home Garden	1733.71833854	138862.127201	0.14	Builtup	1
19	19		19 Home Garden	1445.51485434	67613.2591164	0.07	Builtup	1
20	20		20 Home Garden	2270.19326061	58704.0006069	0.06	Builtup	1
21	21		21 Mixed Crop	1326.44501681	40951.2535784	0.04	Agricultural Lands	2
22	22		22 Agricultural Land	1969.55971315	79753.4005574	0.08	Agricultural Lands	2
23	23		23 Home Garden	1113.24129280	49153.8418755	0.05	Builtup	1
24	24		24 Agricultural Land	783.91632547100	23770.6046468	0.02	Agricultural Lands	2
(PR) Char	All Factors							
Shov	/ All Features 🗶							

5.6 After saving the edits, right-click on the layer and open the layer properties.

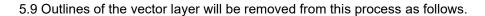


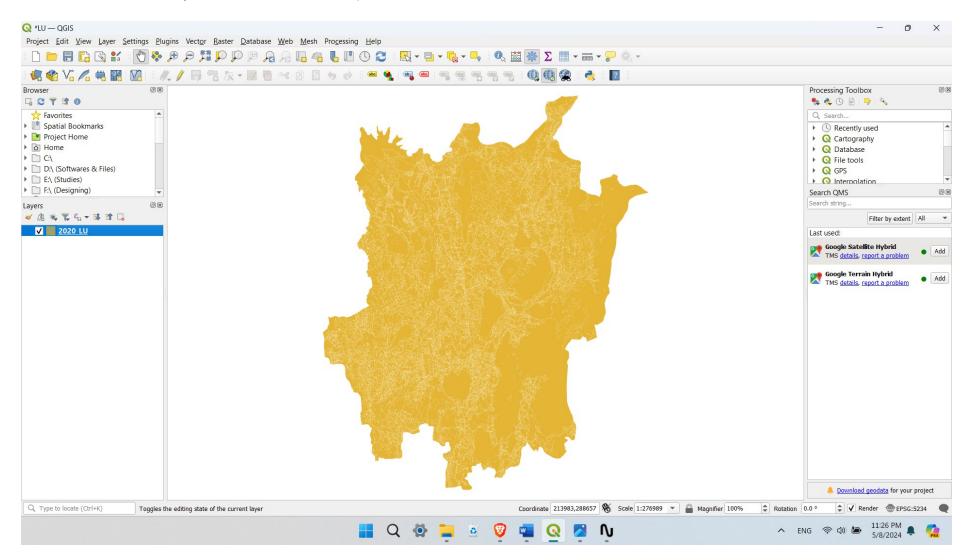


5.7 Go to the "Symbology" properties. Next, click on "Simple Fill". Then expand the "Stroke style".

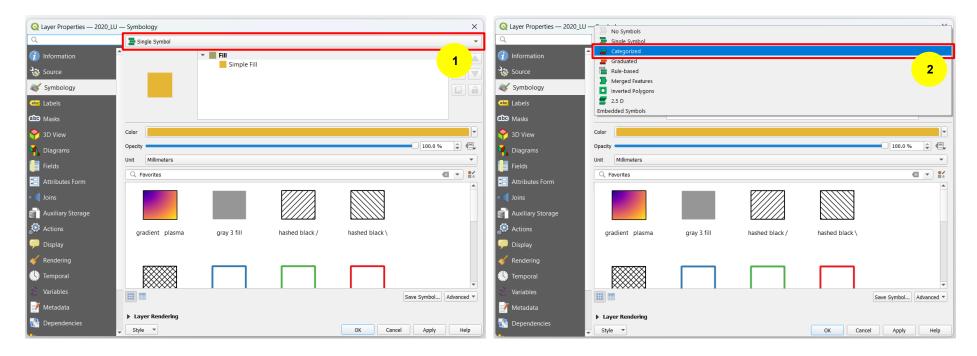


5.8 Select "No Pen" from the expanded list. After that, click on "Apply" and "OK".



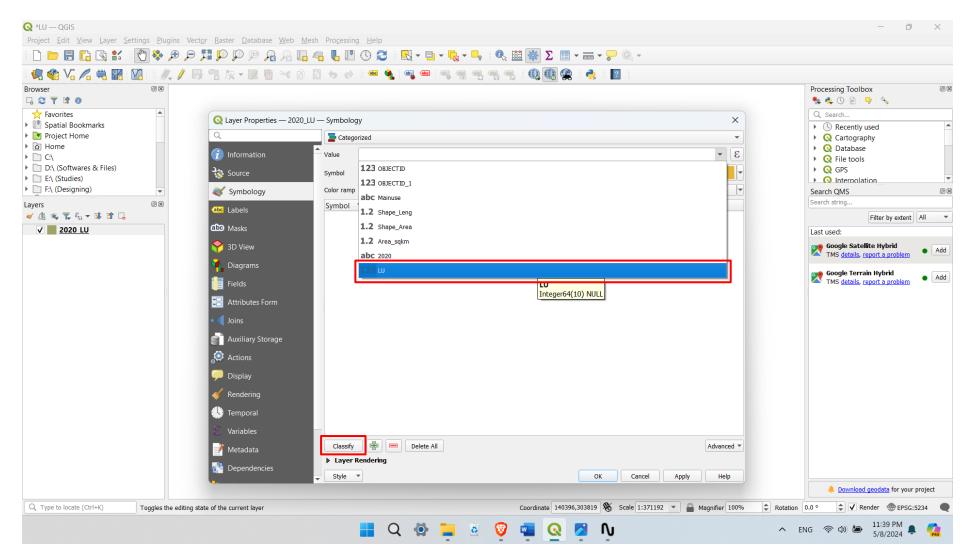


5.10 Let's categorize this vector layer. For that, again open the layer properties and go to the "**Symbology**" properties tab. Then, click on "**Single symbol**" and expand it. Select "**Categorized**" from the expanded list.



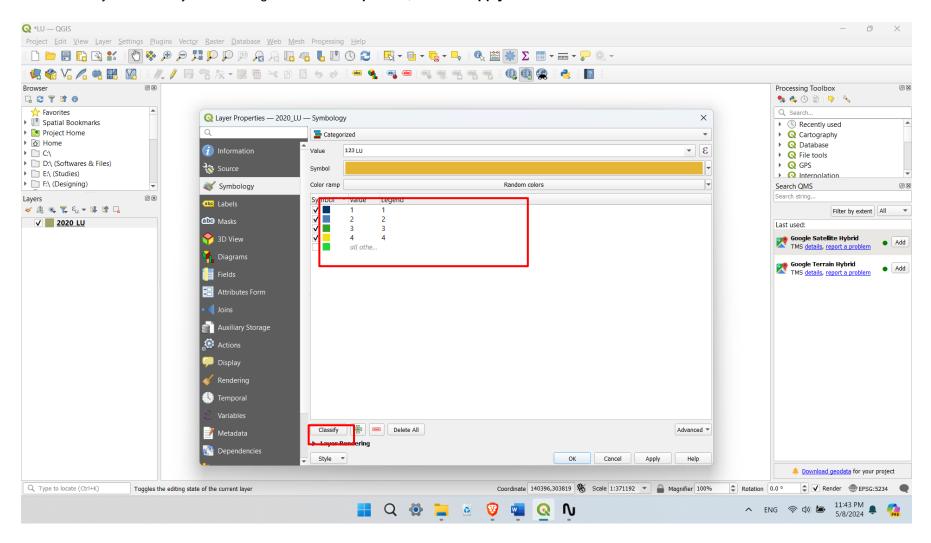
5.11 After selecting the "**Categorized**" option, the controls will be shown here like this. Next, expand the option "**Value**"

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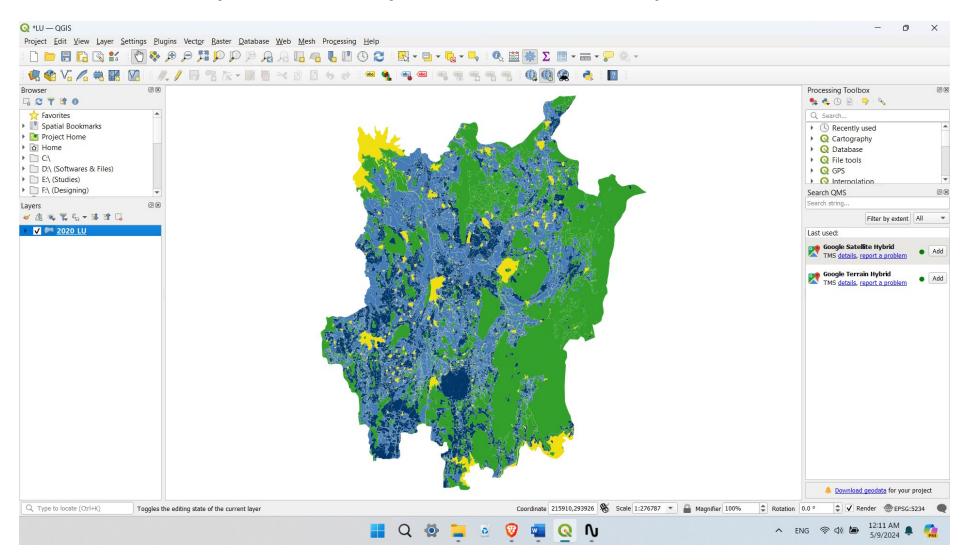


5.12 Select the field "LU" from this expanded list. After selecting the field, click on "Classify".

5.13 The classification will be displayed as follows. If you want to change the colors of each category, double-click on the color from the classification and select the color that you want. Or you can change the **color ramp**. Then, click on **"Apply**" and **"OK**".



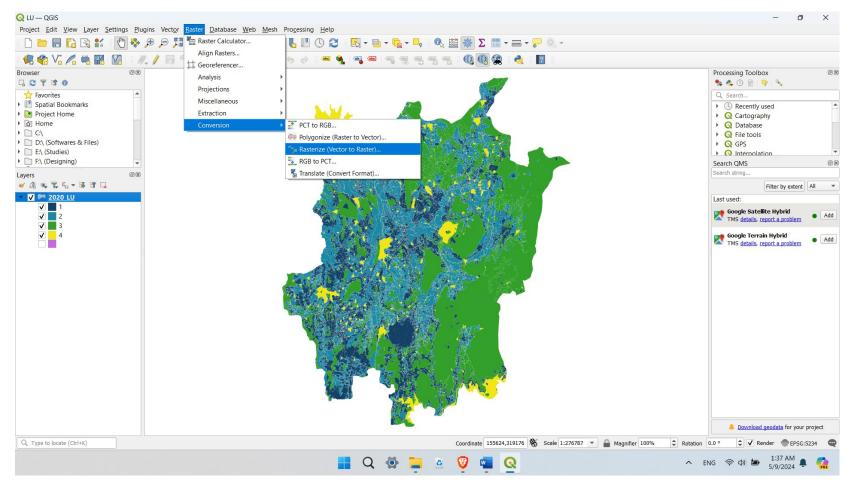
Here is the classification according to the main 4 land use categories, that we introduced to the Dambulla region.



Rasterization with QGIS 3.22.7

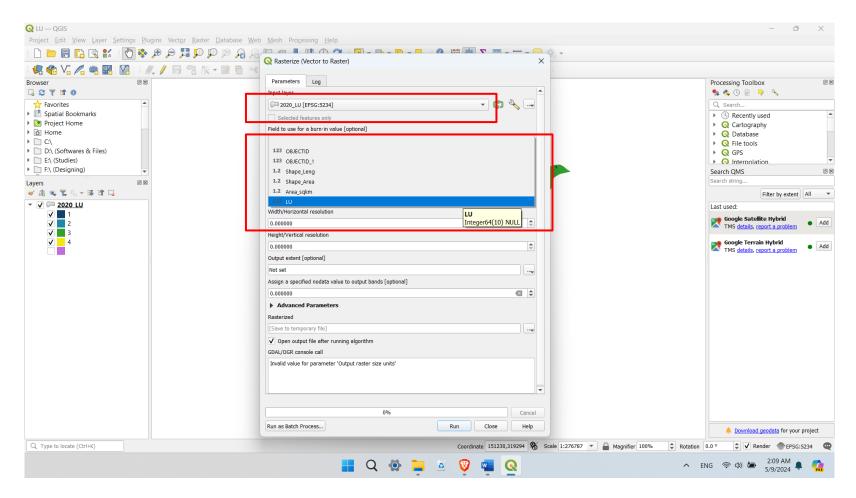
To convert this vector layer into a raster layer, open the "Rasterize" tool as follows.





Then, the Rasterize tool will appear on the screen. Select the layer you want to convert to a raster on the "Input layer".

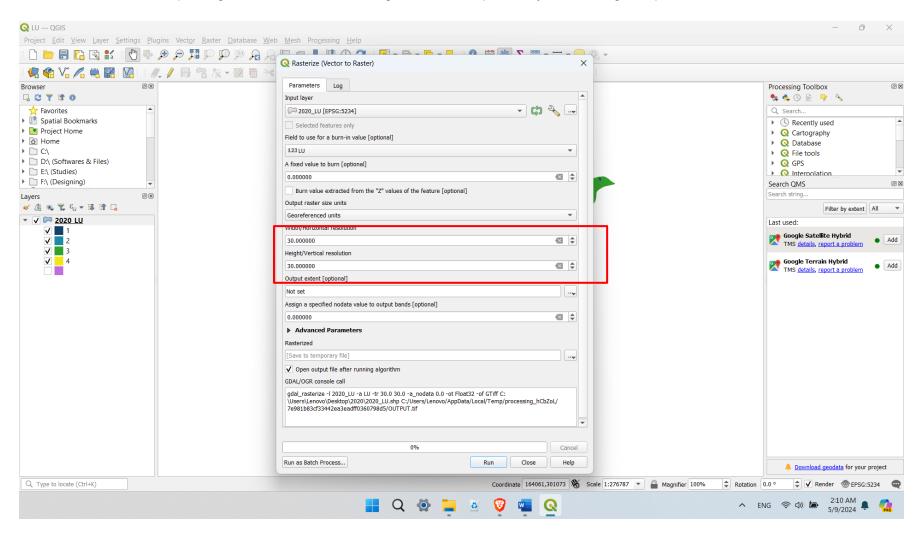
Next, expand the "Field to use for a burn-in value" option and select the numeric field as follows. Here, we are going to rasterize this layer through the field "LU".



Then, select the "Output raster size units" as "Georeferenced units".

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Next, enter the "Width/Horizontal" and "Height/Vertical" resolutions as "**30**". Generally, we use the pixel size of a raster layer as 30x30. That's why we entered the same size here. But depending on the dataset we are using; we can resample the layer and change the pixel size.



Next, we select the output extent. After clicking the icon shown in the corner of that option, we can select the desired layer as below and use the output extent.

Click on the icon > Calculate from layer > Select the layer

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The output extent will be set up according to the above-selected layer as follows.

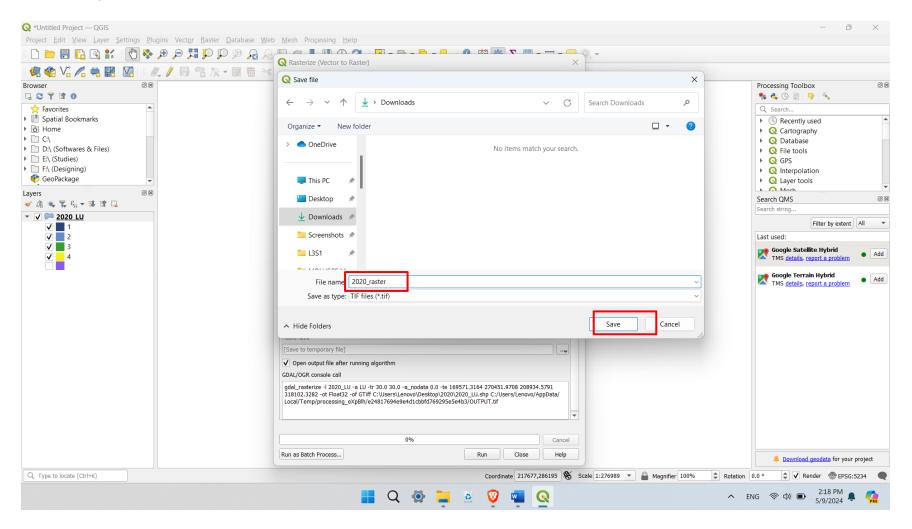
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Then, browse a location to save this layer. For that, click on the below icon and select "Save to File".

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As follows, now you can browse and select a location on your computer to save the layer. Once you select the location and set the **File name** as below, click

on "Save" to proceed.

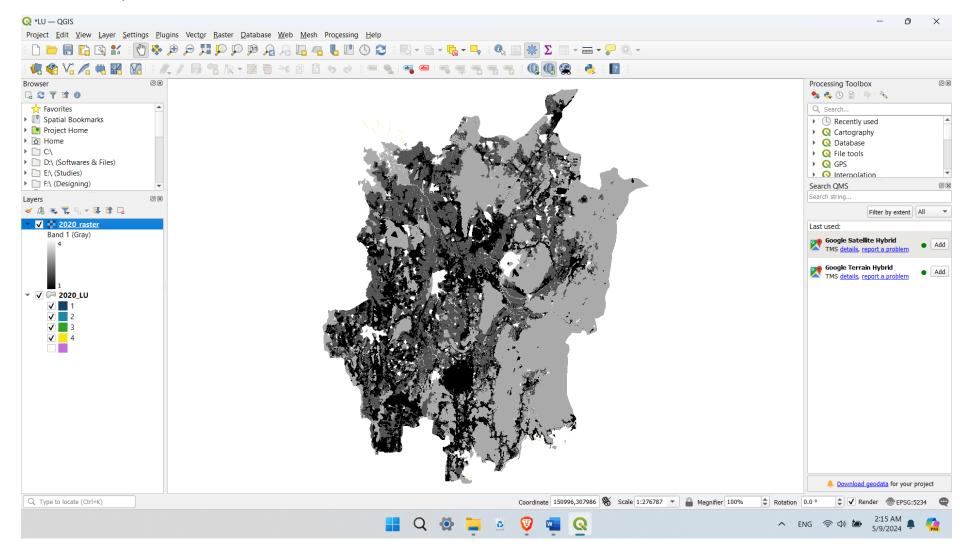


Now all the parameters are ready. Click on "Run".

After this is finished running, a message will appear on the screen as shown in the image below right side.

Rasterize (Vector to Raster)	×	Rasterize (Vector to Raster)
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💭 2020_LU [EPSG:5234] 🗸 🕻		QGIS code revision: 5a65627a Ot version: 5.15.3
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123111	-	PROJ version: Rel. 9.0.0, March 1st, 2022 PDAL version: 2.3.0 (git-version: 0a6ef5)
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		<pre>{ 'BURN' : 0, 'DATA_TYPE' : 5, 'EXTENT' : None, 'EXTRA' : '', 'FIELD' : 'LU', 'HEIGHT' : 30, 'INIT' : None, 'INPUT' : 'C:\\Users\\Lenovo\\Desktop\\2020\</pre>
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Now the raster layer can be seen as follows.



Once the rasterization is finished as above, follow the steps below for ease of identifying their land use categories separately in clear colors.

• Right-click on the layer to open the layer properties and go to the "**Symbology**" tab.

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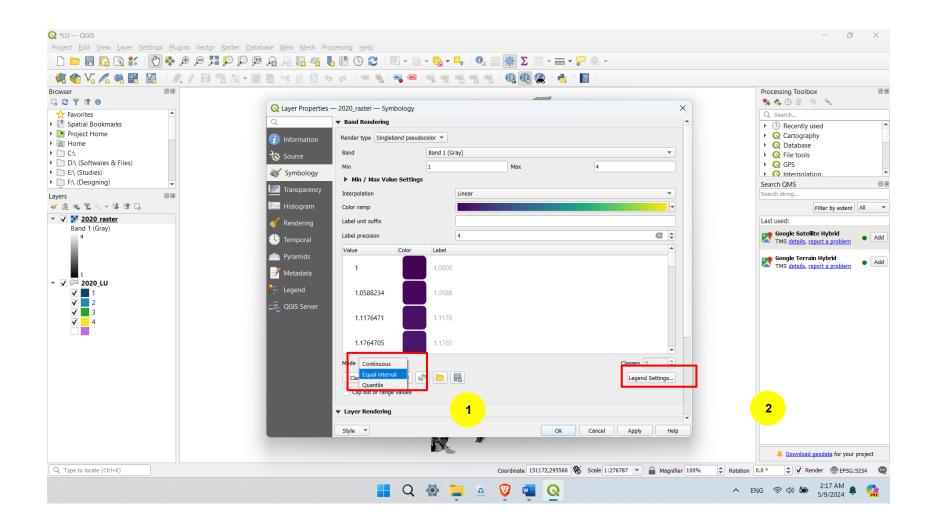
• Set the "Render type" as "Singleband pseudocolor".

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- Set the "Interpolation" as "Linear".
- Then you can select any color combination under "Color ramp".

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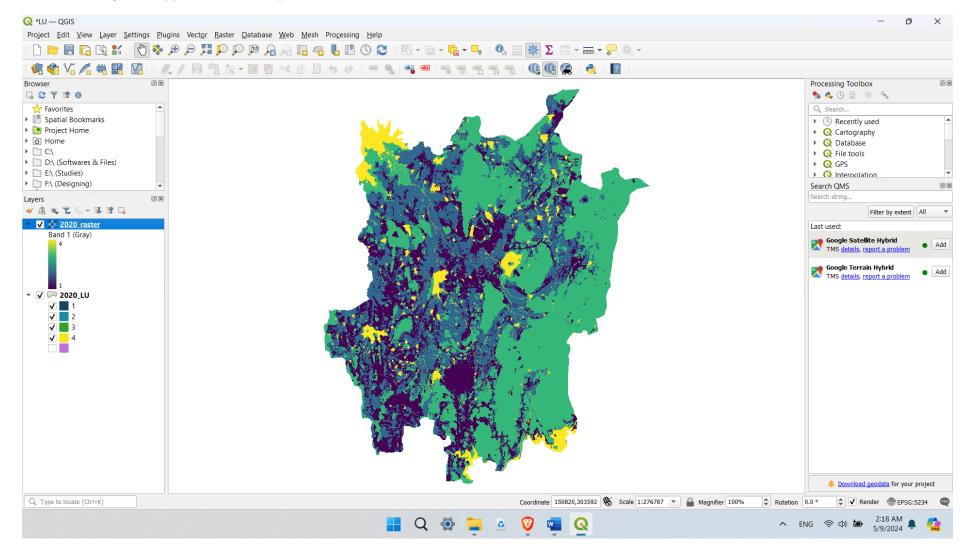
• Set the "Mode" as "Equal Interval" and set the "Classes" as "4". (The number of classes may vary on your land use layer's classification. In this layer, there are 4 land use categories. That's why the number of classes is set as "4")



- After setting the number of classes, click on "Classify".
- Finally, click on "**Apply**" and "**OK**".

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The land use layer will appear on the workspace as follows.



When utilizing the MOLUSCE plugin in QGIS, it's essential to ensure that all input layers have the same number of rows and columns, which ensures matching geometries. This requirement is critical for several reasons,

• Matching geometries

For successful processing in MOLUSCE, the geometries of input rasters must align. This alignment entails having consistent characteristics such as cell size, coordinate reference system (CRS), and spatial extent.

• Why matching geometry matters

During the rasterization process, where vector data (e.g., roads or land use polygons) is converted to raster format, values are assigned to raster cells based on the vector data. Matching geometries ensure that this assignment occurs accurately, with vector data aligning correctly with the raster grid. Consistent geometries also contribute to reliable analysis, as MOLUSCE relies on uniform input data for accurate land use change simulations.

• Steps to ensure matching geometries

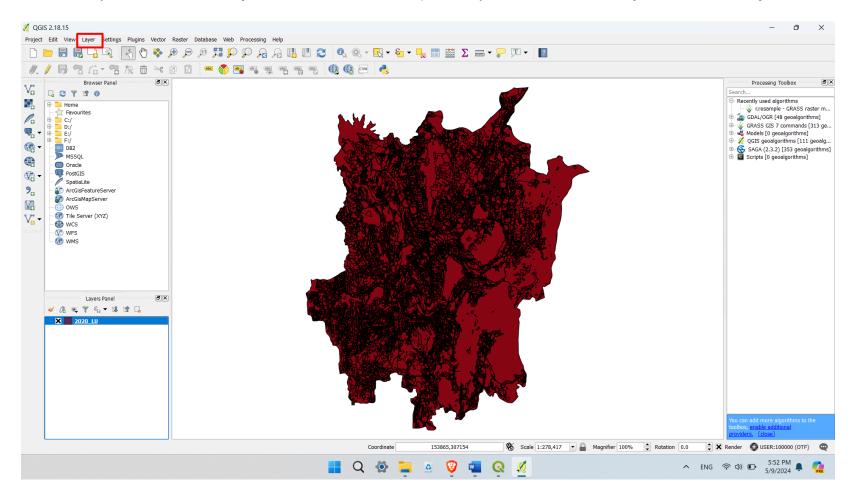
To achieve matching geometries, consider resampling input rasters to a common cell size if variations exist. Additionally, ensure all layers share the same CRS and adjust the extent of the rasters to align properly. By following these steps, we can maintain consistent geometries, leading to accurate and reliable results when utilizing the MOLUSCE plugin for land use change simulations in QGIS.

The rows and columns count of the layers we use here should be 1725 and 1430 respectively, and the cell size should be 0.00025. These values were determined based on the pre-processed dataset we obtained while performing this analysis. Similarly, if you are engaged in this type of project, you need to resample the layers prepared above to adjust the cell size and other parameters as desired. **However, since those steps were not successful through the QGIS version 3.22.7 that we used until now, we hope to use QGIS version 2.18.15 to resample the layers.**

Starting with the step of converting the vector layer to a raster layer, the following is repeated through QGIS version 2.18.15. It shows how to equalize Rows and Columns count and resize cells. And all these can be done very smoothly by using the ArcMap software. Let's examine those steps next.

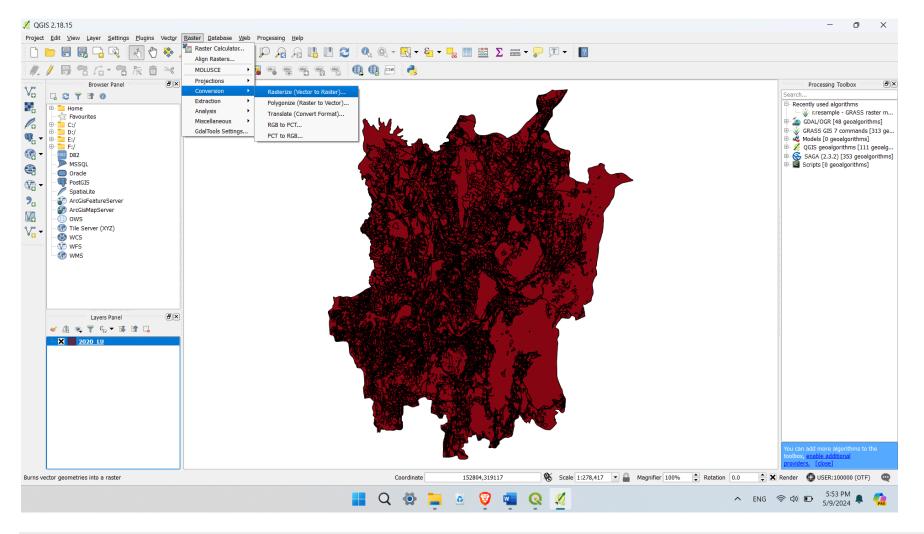
Rasterization with QGIS 2.18.15

- Open the updated land use layer with QGIS 2.18.15 as follows.
- For that, you can click on the "Layer" on the main toolbar and open the layer toolbar. Then, Add Layer > Add Vector Layer

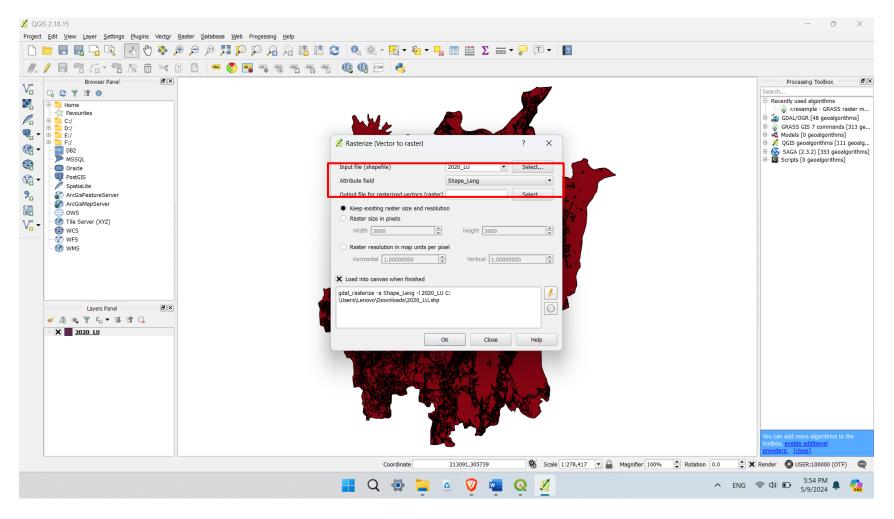


• Now let's convert this vector layer to a raster layer. For that, open the **Rasterize tool**.

Click on the "Raster" on the main toolbar > Conversion > Rasterize (Vector to Raster)

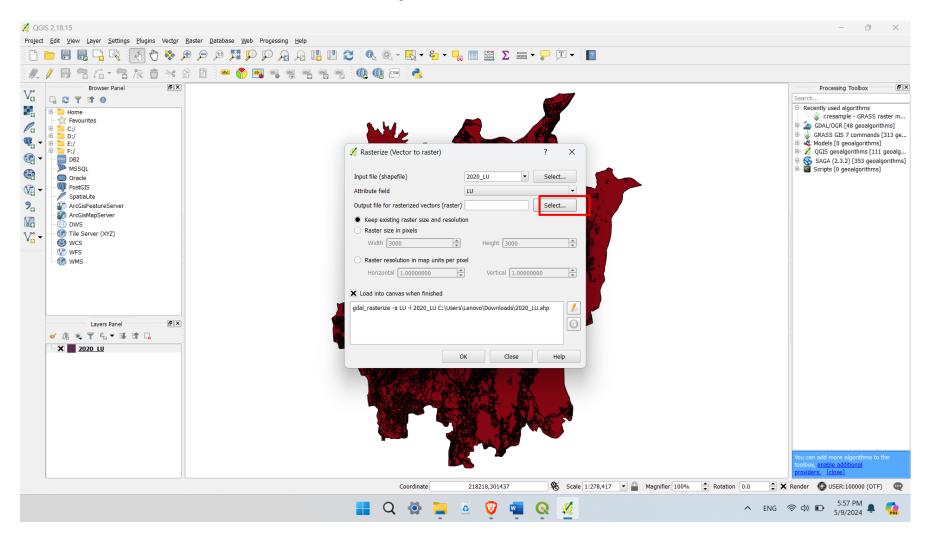


- Then the following window will open. First, select the vector layer as the Input file (shapefile) here.
- Next, we have to select the **Attribute field**. As you may remember, this rasterization process is done based on the field we select here. And, this field should be **numeric**.

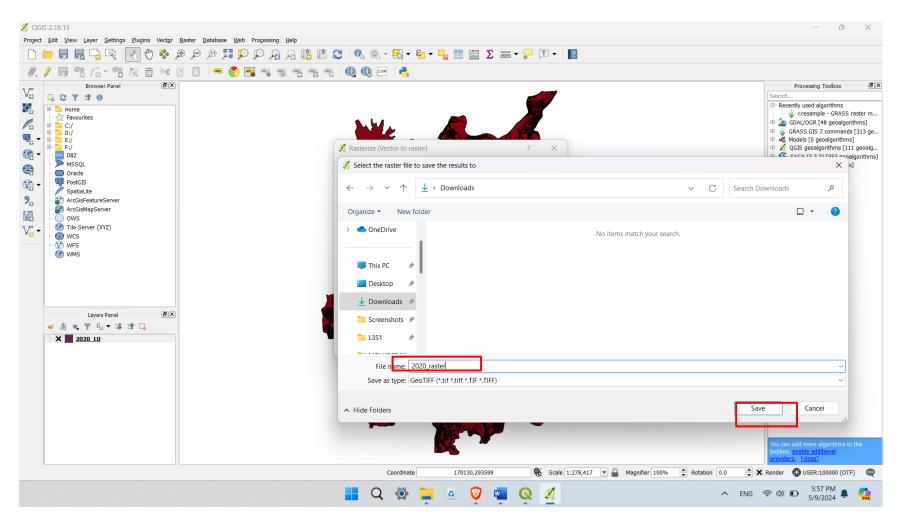


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- As selected in QGIS version 3.22.7, select the "LU" field here as well.

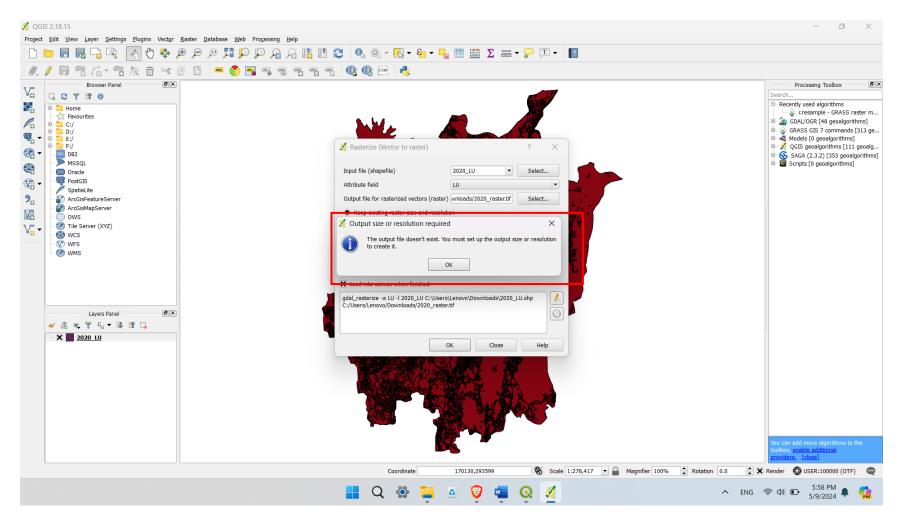
- The selected field will be shown as follows.
- Next, click on "Select" to browse a location for the saving results.



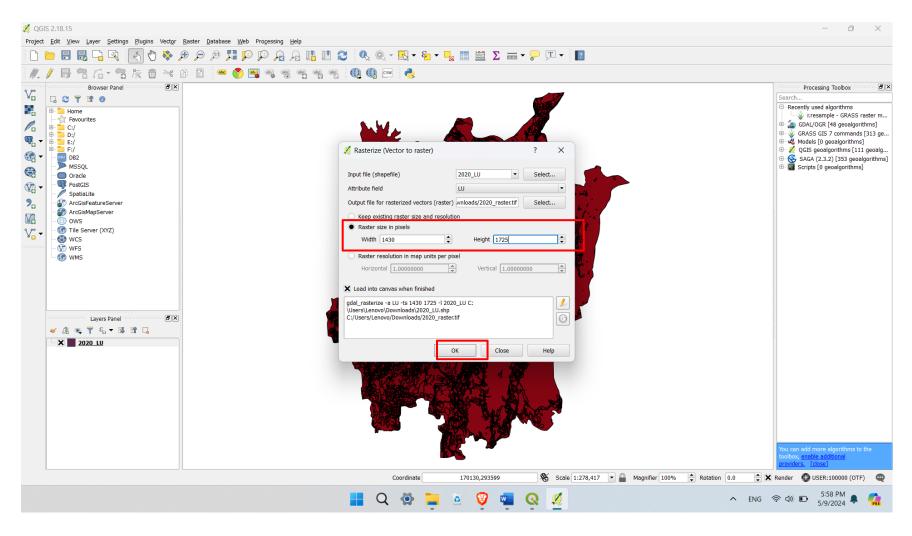
- Then, the following window will open on the screen. Select a suitable location as your preference and give a **file name**.
- Click on "Save".



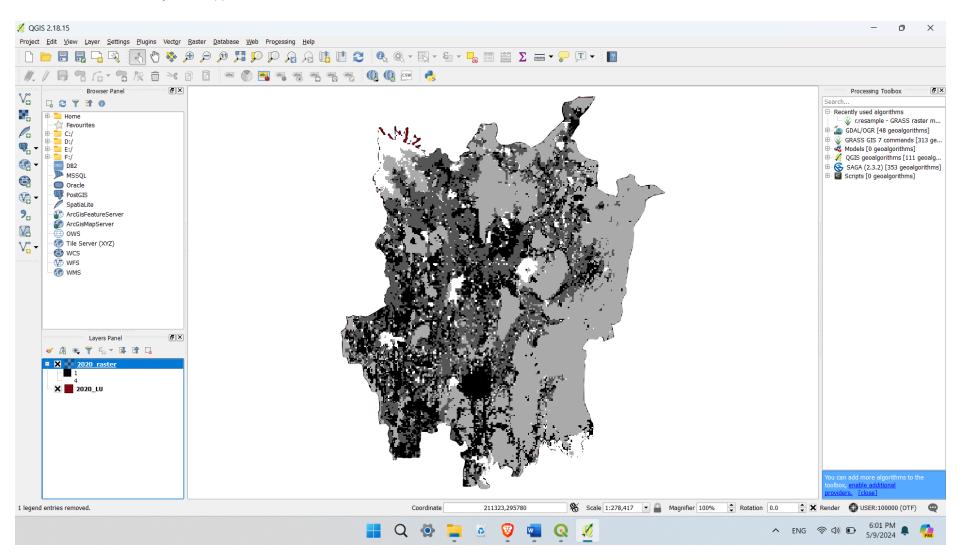
- The following warning message will appear on the screen. According to that, you have to set up the output resolution as you need for the raster layer.
- Click on "**OK**" to proceed to set up the resolution.



- Set up the values here as same as before.
- Click on "**OK**" to run the tool.



• The rasterized layer will appear on the screen as follows.



- Right-click on the layer and open the layer properties as follows.
- Under the general properties of the layer, now you can check the columns and rows values and the coordinate reference system.

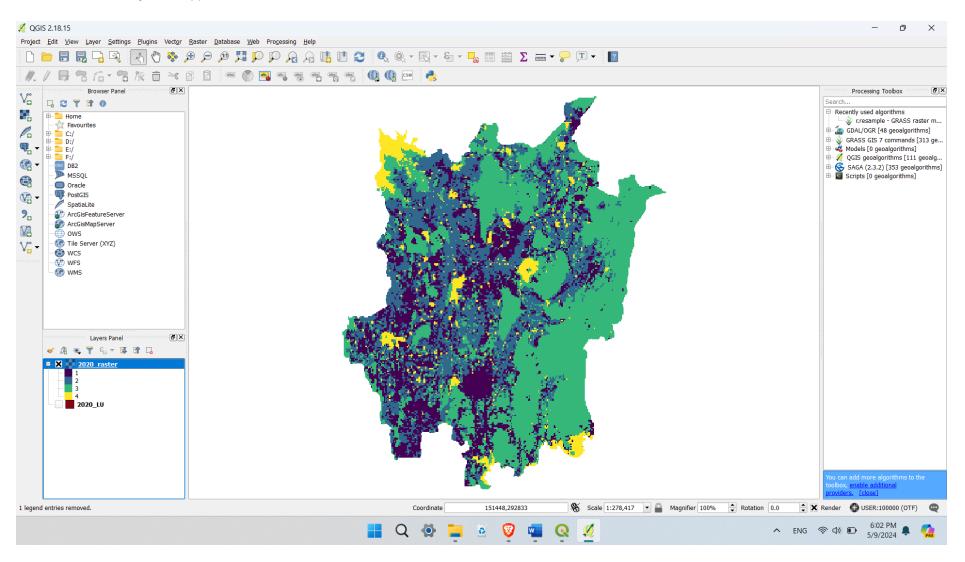
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• Go to the style properties and set up the following settings as same as before in the QGIS 3.22.7.

• This will provide a clear color combination to easily identify the land use categories.

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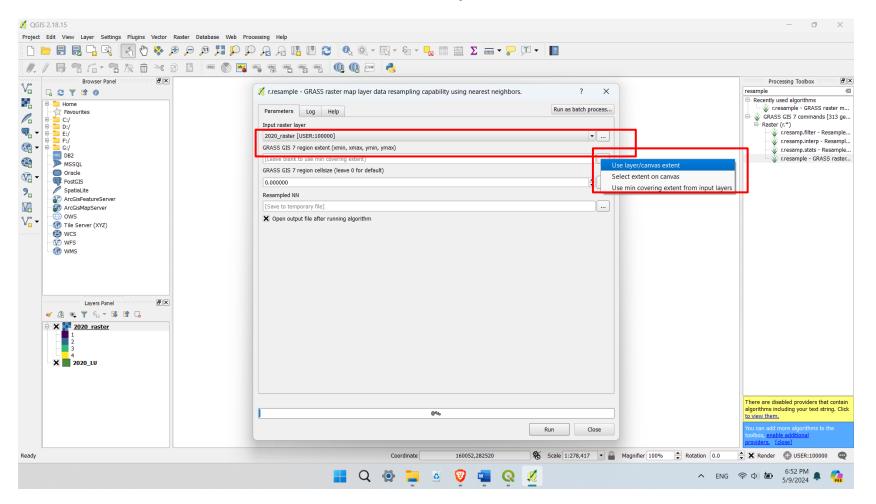
• The raster layer will appear on the screen with the new color combination as follows.



- In the next step, we have to set up the cell size. For that, search for the "**resample**" tool in the processing toolbox.
- Select the newly rasterized layer as for the "Input raster layer" here.

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- Next, we have to set up the **region's extent**.
- For that, click on the icon that contains 3 dots, and click on "Use layer/canvas extent".



- Then, the following window will appear on the screen.
- Expand the list and select the layer that you want to use as the region extent for this raster layer.
- This extent of the region will be used for the extent of the new raster layer during the resampling process.

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- The extent will be shown as follows.
- Next, enter the cell size that you want. After that, click on "Run" to proceed.

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Rasterization with ArcMap

ArcMap is a comprehensive Geographic Information System (GIS) software developed by Esri, widely used for mapping and spatial analysis. It is not opensource software; rather, it is a commercial product that requires a license for use. Despite this, it is renowned for its robust features, ease of use, and extensive support and documentation.

Converting a vector layer to a raster layer can indeed vary in complexity between different GIS software. ArcMap generally offers a more user-friendly experience for this process compared to QGIS, primarily due to its more streamlined and integrated toolset. ArcMap's interface and tools are designed to facilitate easier conversion and resampling with fewer steps and more intuitive options.



On the other hand, QGIS, being an open-source platform, sometimes presents challenges with tool consistency and ease of use. While QGIS has made significant improvements over the years and offers robust functionality, some users may encounter issues such as tool compatibility, less intuitive workflows, and occasional bugs during conversion and resampling processes. QGIS's flexibility and extensive plugin ecosystem, including tools like MOLUSCE, provide powerful capabilities for advanced users who are familiar with its interface. Additionally, QGIS's open-source nature means that it is continually evolving, with a strong community contributing to its development and troubleshooting issues.

While ArcMap might offer a more straightforward and user-friendly experience for converting vector layers to raster layers, QGIS remains a powerful alternative, especially for those who can navigate its more complex toolset. Since QGIS is an open-source software, here we tried to use it for the entire process. But for this, you can also use ArcMap software like this.

2.2 Preparation of the layers for spatial variables

This part is the most important part of this analysis. Because the prediction of future land use change depends on these layers. In the area that we took as the sample study area, from 2005 to 2020, the reasons that affected the change in its land use should be considered here. Generally, some reasons mainly affect the rapid changes in land use of a particular area.

- Warfare and Armed Conflict
- Economic Crises and Institutional Overhaul
- Population Growth and Urbanization
- Technological Advancements and Infrastructure Development
- Climate Change and Natural Disasters
- Policy and Land Reforms
- Technological Diffusion and Innovation

Rapid changes in land use happen because of different reasons, both natural and man-made. One big reason is warfare and armed conflict. When there's fighting, it affects places where lots of people live, no matter what kind of land it is. The effects of war on land can be different and can last a long time.

Another big reason is when there are economic problems or big changes in how things are run. When money gets tight or when there are big changes in how the government works, it can suddenly change how land is used. For example, it might lead to things like cutting down trees illegally or changing from growing crops for money to growing food to eat at home.

Then there's population growth and cities getting bigger. More people need more land, so places where food is grown might get turned into cities. When new roads or buildings are built, it changes the land too. Climate change and disasters like floods or wildfires can mess up the land. All these things, plus rules about land and new technologies, like better ways to grow crops or use solar power, all play a big part in how land is used.

In the case of **Dambulla**, during the period considered above, no special reason has affected the land use of the area. But with the development of the country during the considered period (infrastructure development related to transportation, housing, agriculture, etc.), the built-up area of this region has increased significantly; especially the Municipal Council area. Population growth and rapid urbanization must be another reason for this.

According to our collective studies of the Dambulla area, these were identified as factors that somehow influenced its land use change between 2005 and 2020.

- 1. Environmentally sensitive areas
- 2. Road density
- 3. Euclidean distances between roads
- 4. Euclidean distances to the nearest town centers
- 5. Population density
- 6. Access to services
- 7. Accessibility
- 8. Land use efficiency
- 9. Building density

Separate layers should be created for each of these factors, and their rows, columns, and geometries should be the same as the previously created land use layers. If there is any problem and it is not the same, then the mistakes should be corrected as mentioned before. Next, let's see how we can create raster layers for these spatial variables. There are 9 variables shown here, and how to prepare the required raster layers for the following spatial variables is presented in several separate books.

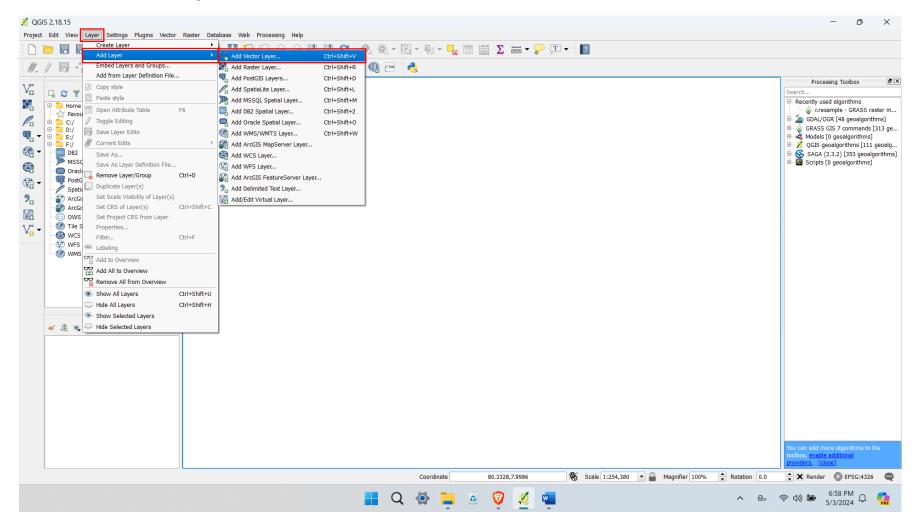
- Land use efficiency (Refer to the book)
- Building density (Refer to the book)

1. Environmentally sensitive areas

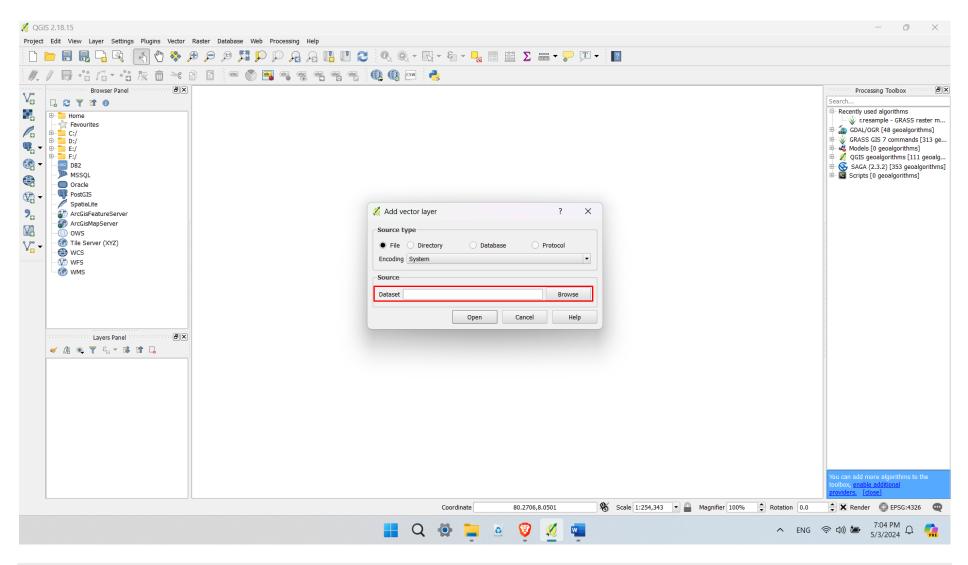
Here we use the "environmentally sensitive areas" of the area which is considered as a spatial variable. Generally, environmentally sensitive areas are protected by the government. Also, no permission is given for construction in those areas. To create this layer, first, open the land use layer of the Dambulla area.

- 1. Click on the "Layer" on the main toolbar and open the layer toolbar.
- 2. Then, click on "Add Layer".

3. Next, click on "Add Vector Layer".



Now, the following window will appear on the screen and you can browse the vector file that you want to open.



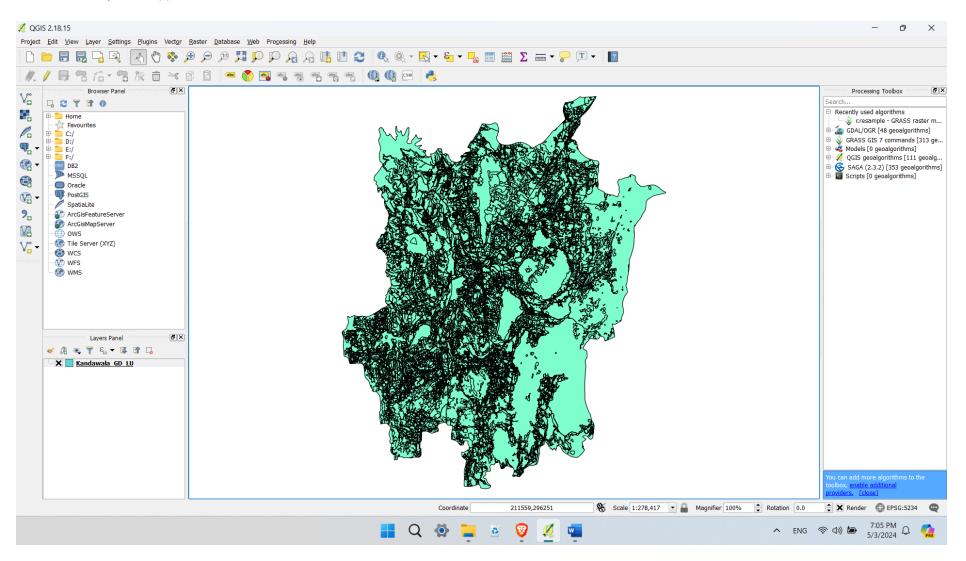
After clicking on "**Browse**", the following window will open. Then, go to the relevant folder and select the vector file. Usually, a shape file consists of 6 other files. The file type you should choose to open here is the "**AutoCAD Shape Source**" file. As per the instructions, click on that layer, and after that click on "**Open**".

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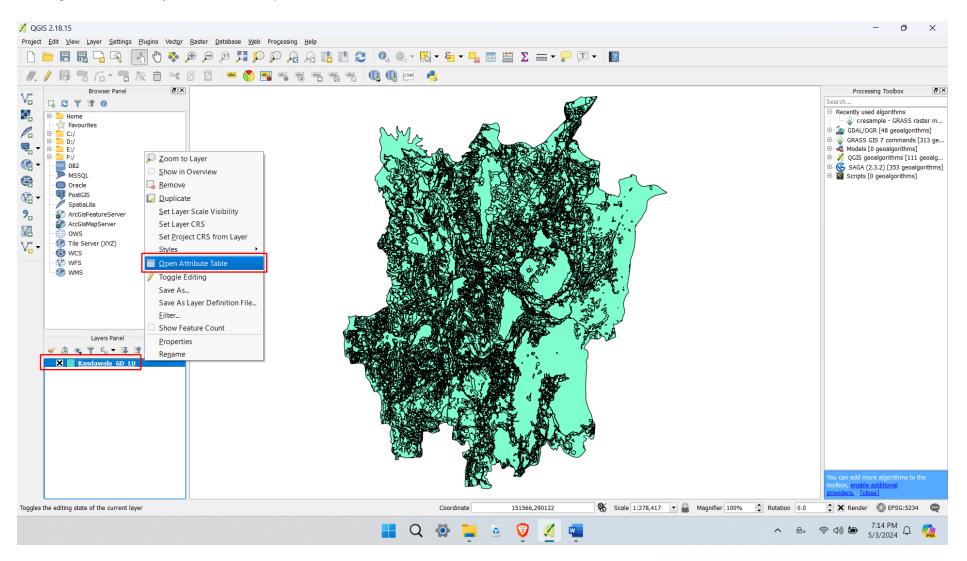
Again, click on "**Open**" to add the layer to the workspace.

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The land use layer will appear on the screen as follows.



Now, right-click on the layer and click on "Open Attribute Table".



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	4	4		Paddy		1689.1721519	46418.289935	. Agricultural	0.05	Agri	Agri				
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	7	7 Home Garden		Home Garden		919.44471945	38852.270967	. Recreational	0.04	Builtup	Builtup				
	8	8 Home Garden		Home Garden		1713.6064177	128459.21254	. Recreational	0.13	Builtup	Builtup				
	9	9 Home Garden		Home Garden		935.08365697	47755.462312	. Recreational	0.05	Builtup	Builtup				
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	13	13		Home Garden		852.31742858	18421.476763	. Recreational	0.02	Builtup	Builtup				
	14	14 Forest		Forest		17135.849144	5175386.4355	. Vegetation	5.18	Vegetation	Vegetation				
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;	16	16		Paddy		1350.5142022	57605.559316	. Agricultural	0.06	Agri	Agri				
	17	17		Home Garden		1845.3138304	79789.010855	. Recreational	0.08	Builtup	Vegetation				
3	18	18		Home Garden		1733.7183385	138862.12720	. Recreational	0.14	Builtup	Builtup				
•	19	19		Home Garden		1445.5148543	67613.259116	. Recreational	0.07	Builtup	Builtup				
	20	20		Home Garden		2270.1932606	58704.000606	. Recreational	0.06	Builtup	Builtup				
1	21	21		Mixed Crop		1326.4450168	40951.253578	. Agricultural	0.04	Agri	Agri				
2	22	22		Agricultural L		1969.5597131	79753.400557	. Agricultural	0.08	Agri	Agri				
3	23	23		Home Garden		1113.2412928	49153.841875	. Recreational	0.05	Builtup	Builtup				
ŧ	24	24		Agricultural L		783.91632547	23770.604646	. Agricultural	0.02	Agri	Agri				
	25	25		Agricultural L		759.97365985	23326.201194	. Agricultural	0.02	Agri	Agri				
5	26	26		Mixed Crop		786.68598156	24421.429252	. Agricultural	0.02	Agri	Agri				
	27	27 Forest		Forest		3729.5682624	263509.36147	. Vegetation	0.26	Vegetation	Vegetation				
3	28	28		Home Garden		1255.8742652	29062.847610	. Recreational	0.03	Builtup	Builtup				
	29	29		Agricultural L		1202.7812016	38856.345101	. Agricultural	0.04	Agri	Agri				
)	30	30		Agricultural L		1170.6508047	29991.599575	. Agricultural	0.03	Agri	Agri				
7 Sho	w All Features													l	

The Attribute Table of the layer will open as follows. Under the column "Mainuse", we can see the land use of every plot of the Dambulla regional area.

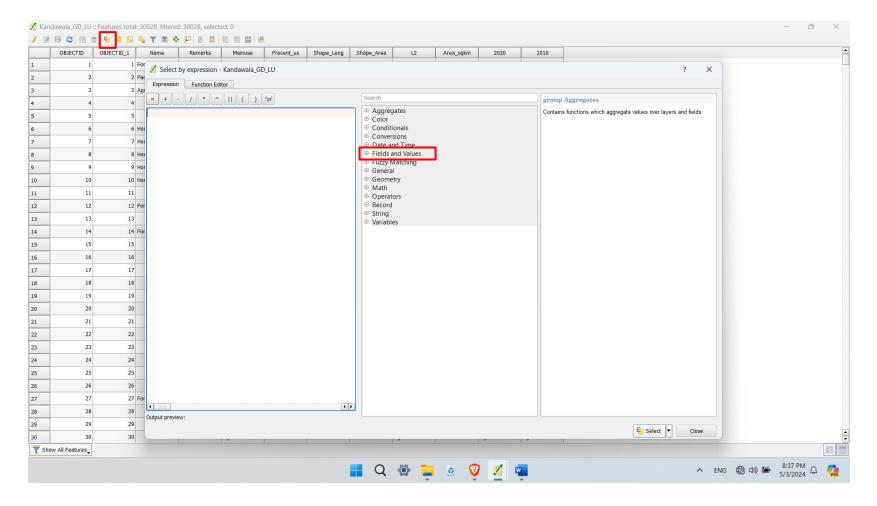
Considering these land use categories related to the Dambulla area, we divided their environmental sensitivity into 3 classes. This classification is based on the potential impact each land use category may have on the environment, considering factors such as habitat disturbance, biodiversity loss, pollution, and conservation importance.

1	Environmental Sensitivity of Greater Dambull	a
Low Environmental Sensitivity (1)	Medium Environmental Sensitivity (2)	High Environmental Sensitivity (3)
 Aviation Bank and Allied Commercial/Residential Commercial Dam Educational Grassland Health Home garden Industrial Institutional Open space Other plantation Other roads RDA road Railway Rock Socio-cultural places Sports and amusement Stores and warehouse Transportation Under-construction sites Utility Vacant buildings Unclassified areas 	 Abandoned tank Agricultural land Coconut plantation Mixed crop Paddy fields Plantations (other than coconut) Religious place Tourism Vacant lands 	 Archaeological places Catchment area Forest Marshy River Scrub Water bodies

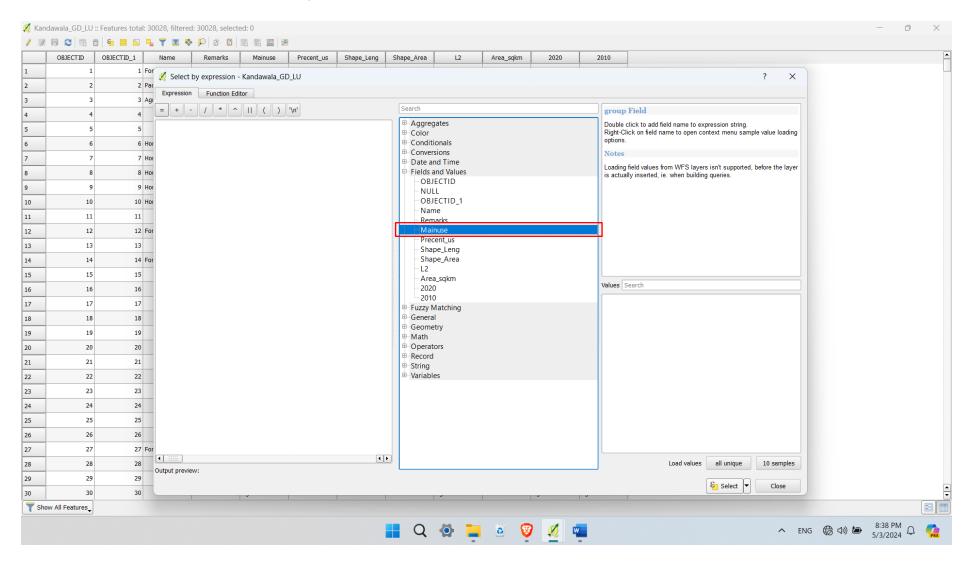
Table 5 -Categorization of the environmental sensitivity

Now we can check, how many land use categories are contained under the "Mainuse" column. For that,

- 1. Click on the "Select by expression" tool. Then, the following window will open.
- 2. Click on the "+" mark and expand the "Fields and Values". Or you can double-click on the "Fields and Values" to expand it.

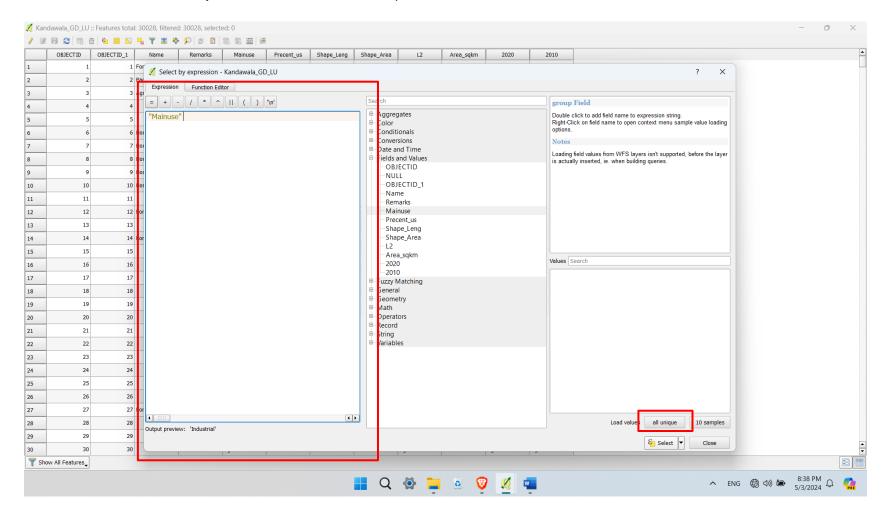


After that, double-click on "Mainuse" from the expanded list.



If you properly double-click on that, it will be shown in the expressions tab as follows.

• Then, click on "all unique". It is used to see the all uniques under the selected field.



According to the previous step, all the unique related to "Mainuse" will be shown as follows.

L	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Area_sqkm	2020	2010	
	1	1 For	💋 Select	by expression	- Kandawala	GD LU							? ×
	2	2 Pa		Function Ed	litor	-							
	3	3 Ag						Search					
	4	4		· / * ^		./u.		Aggree	antos				oup Field
	5	5	"Mainuse					ter Color	gates			Rig	uble click to add field name to expression string. ht-Click on field name to open context menu sample value loading
	6	6 Ho						Condit Conver					ions.
	7	7 Ho											otes
	8	8 Ho							and Values			Loa is a	ading field values from WFS layers isn't supported, before the layer actually inserted, ie. when building queries.
	9	9 Ho						- NUI	JECTID LL				
	10	10 Ho							JECTID_1				
	11	11						- Nar Rem	me narks				
	12	12 For						Mai	inuse				
	13	13							cent_us ipe_Leng				
	14	14 Fo						Sha	pe_Area				
	15	15						L2	a_sqkm				
	16	16						- 202	0			·	les Search
	17	17						- 201 - Fuzzy M					pondon Tank'
	18	18						🕀 Genera	al			'Ar	chaeological Places'
	19	19						⊞ Geome ⊞ Math	etry				riation' ank & Allied'
	20	20						🗄 🕀 Operat					atchment Area'
	21	21						Record String	1				nena' poconut'
	22	22						Variabl	les			'Co	om/Resi'
	23	23											ommercial' am'
	24	24										'Ed	ducational'
	25	25											orest' rass Land'
	26	26											ealth'
	27	27 For										'Ho	ome Garden'
	28	28					•						Load values all unique 10 samples
	29	29	Output previe	w: 'Industrial'									
	30	30									5	5	Gelect Close
Show	All Features												

Now, we have to select land use categories under these 3 sensitivity classes, and we can give a value to each class and enter those values in the attribute table. According to these, we can use **1 for low sensitivity**, **2 for medium sensitivity**, **and 3 for high sensitivity**.

- First, we should create a new field in the attribute table named "Env_Sens".
- Click on the pencil icon and turn on the "Toggle editing mode".

ggle e	editing mode (Ctrl+E) 1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2
.35	135		Home Garden		Home Garden		1572.0575592	29012.700455	Recreational
136	136	136	Home Garden		Residential		183.41696887	2127.5125698	Residential
137	137	137	Agriculture		Agricultural L		406.27829373	5088.6080518	Agricultural
138	138		Agriculture		Agricultural L			14046.275678	-
139	139		Other Road		Other Road			393.79835570	-
140	140		Other Road		Other Road			4716.2478129	
141	141		Other Road		Other Road			11876.892761	
142	142		Other Road		Other Road			7942.2790886	
	142		Other Road						
143					Other Road			1243.4290179	
144	144		Other Road		Other Road			503.59954561	
145	145		Other Road		Other Road			2372.2912603	
146	146		Other Road		Other Road			39.174135890	
147	147		Other Road		Other Road			291.89928029	
148	148	148	Other Road		Other Road			1067.3883965	
149	149	149	Other Road		Other Road		253.05794024	370.37823791	Transportation
150	150	150	Other Road		Other Road		1399.9173100	2085.2591467	Transportation
151	151	151	Other Road		Other Road		443.68163905	656.52328238	Transportation
152	152	152	LA Road		Other Road		8480.2876979	14821.312527	Transportation
153	153	153			Scrub		289.90123489	655.79645462	Vegetation
154	154	154			Scrub		440.70526926	1423.6105749	Vegetation
155	155	155	Water Bodies		Water Bodies		5401.3995401	37031.925701	Water Bodies
156	156	156	Water Bodies		Water Bodies		2249.6653069	11832.371254	Water Bodies
157	157	157			Scrub		1734.9003544	32224.807303	Vegetation
158	158	158	Paddy		Paddy		1405.6878182	89066.918467	Agricultural
159	159	159	Home Garden		Home Garden		1026.7610499	35470.893797	Recreational
160	160	160	Agriculture		Agricultural L		483.24900122	8626.2173244	Agricultural
161	161	161	-		Scrub			9251.0425208	-
162	162	162			Scrub			2336.3694521	-
163	163	163			Scrub			2115.2978551	-
164	164		Teak		Plantation			2811.6846871	-
		101	-cuk		, iditation		215155102000111	2011:00 1007 1	regetation
1	All Features								

3 OE	IECTID 🔻 =	3			New field (Ctrl-	-W)				▼ Up	date All
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2		
15	135	135	i Home Garden		Home Garden		1572.0575592	29012.700455	. Recreational		
36	136	136	i Home Garden		Residential		183.41696887	2127.5125698	. Residential		
37	137	137	Agriculture		Agricultural L		406.27829373	5088.6080518	. Agricultural		
38	138	138	3 Agriculture		Agricultural L		749.24850333	14046.275678	. Agricultural		
39	139	139	Other Road		Other Road		268.63809295	393.79835570	. Transportation		
40	140	140	Other Road		Other Road		3151.2409962	4716.2478129	. Transportation		
41	141	141	Other Road		Other Road		7927.2279571	11876.892761	. Transportation		
42	142	142	2 Other Road		Other Road		5305.7305048	7942.2790886	. Transportation		
43	143	143	Other Road		Other Road		835.45983964	1243.4290179	. Transportation		
44	144	144	Other Road		Other Road		341.85531339	503.59954561	. Transportation		
45	145	145	Other Road		Other Road		1587.9240328	2372.2912603	. Transportation		
46	146	146	o Other Road		Other Road		32.405073394	39.174135890	. Transportation		
47	147	147	Other Road		Other Road		200.62409456	291.89928029	. Transportation		
48	148	148	Other Road		Other Road		717.78431239	1067.3883965	. Transportation		
49	149	149	Other Road		Other Road		253.05794024	370.37823791	. Transportation		
50	150	150	Other Road		Other Road		1399.9173100	2085.2591467	. Transportation		
51	151	151	Other Road		Other Road		443.68163905	656.52328238	. Transportation		
52	152	152	LA Road		Other Road		8480.2876979	14821.312527	. Transportation		
53	153	153	3		Scrub		289.90123489	655.79645462	. Vegetation		
154	154	154	ł		Scrub		440.70526926	1423.6105749	. Vegetation		
55	155	155	Water Bodies		Water Bodies		5401.3995401	37031.925701	. Water Bodies		
56	156	156	Water Bodies		Water Bodies		2249.6653069	11832.371254	. Water Bodies		
57	157	157	7		Scrub		1734.9003544	32224.807303	. Vegetation		
58	158	158	B Paddy		Paddy		1405.6878182	89066.918467	. Agricultural		
59	159	159	Home Garden		Home Garden		1026.7610499	35470.893797	. Recreational		
160	160	160	Agriculture		Agricultural L		483.24900122	8626.2173244	. Agricultural		
61	161	161			Scrub		430.69756366	9251.0425208	. Vegetation		
62	162	162	2		Scrub		212.07968185	2336.3694521	. Vegetation		
163	163	163	3		Scrub		179.65238398	2115.2978551	. Vegetation		

Now the layer is in editable mode. Then, click on the icon for "**New field**" as follows.

After clicking on the "New field" icon, the following window will open. Enter the Name as "Env_Sens" and keep the other settings default. We can keep the length of the integer as 1, because there are only 3 classes that we are going to use in this.

		eatures total: 30028, filterec 🔄 🚍 🔊 🔩 🍸 🖺 🗞													_	Ð	×
															✓ Update /	All Update Sel	lected
	OBJECTID C	DBJECTID_1 Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2									2
135	135	135 Home Garden	Hom	ne Garden	_		29012.700455.	. Recreational									
136	136	136 Home Garden	Resi	idential		183.41696887	2127.5125698.	. Residential									
137	137	137 Agriculture	Agri	icultural L		406.27829373	5088.6080518.	. Agricultural									
138	138	138 Agriculture	Agri	icultural L		749.24850333	14046.275678.	. Agricultural									
139	139	139 Other Road	Othe	er Road		268.63809295	393.79835570	. Transportation									
L40	140	140 Other Road	Othe	er Road		3151.2409962	4716.2478129	. Transportation									
141	141	141 Other Road	Othe	er Road		7927.2279571	11876.892761	. Transportation									
142	142	142 Other Road	Othe	er Road		5305.7305048	7942.2790886	. Transportation									
143	143	143 Other Road	Othe	er Road		835.45983964	1243.4290170	Transportation									
144	144	144 Other Road	Othe	er Road		341.85531339	503.5995 🕺	Add field	? ×								
145	145	145 Other Road	Othe	er Road		1587.9240328	2372.291 Nam	e Env_Ser	s								
146	146	146 Other Road	Othe	er Road		32.405073394	30 17413	ment	5	i l							
.47	147	147 Other Road	Othe	er Road		200.62409456			umber (integer)	- -							
48	148	148 Other Road	Othe	er Road		717.78431239	1067.388 Prov	ider type integer		_							
149	149	149 Other Road	Othe	er Road		253.05794024	370.3782 Leng	th 1	×								
150	150	150 Other Road	Othe	er Road		1399.9173100	2085.259			_							
151	151	151 Other Road	Othe	er Road		443.68163905	656.5232	C	K Cancel								
152	152	152 LA Road	Othe	er Road		8480.2876979	14821.31 <mark>2527</mark>	. Transportation									
153	153	153	Scru	ub		289.90123489	655.79645462	. vegetation									
154	154	154	Scru	ub		440.70526926	1423.6105749	. Vegetation									
.55	155	155 Water Bodies	Wat	er Bodies		5401.3995401	37031.925701	. Water Bodies									
.56	156	156 Water Bodies	Wat	er Bodies		2249.6653069	11832.371254	. Water Bodies									
157	157	157	Scru	ub		1734.9003544	32224.807303.	. Vegetation									
158	158	158 Paddy	Pade	dy		1405.6878182	89066.918467	. Agricultural									
159	159	159 Home Garden	Hom	ne Garden		1026.7610499	35470.893797.	. Recreational									
160	160	160 Agriculture	Agri	icultural L		483.24900122	8626.2173244	. Agricultural									
161	161	161	Scru	ub		430.69756366	9251.0425208	. Vegetation									
162	162	162	Scru	ub		212.07968185	2336.3694521	. Vegetation									G
163	163	163	Scru	ub		179.65238398	2115.2978551	. Vegetation								(1
🍸 Sho	w All Features															2	
							Q 🚯	- 0	🦁 🧕 🖷	C	Ň		^	ENG 🛜	(1) 1:29 5/4/2	2024 🗘 🍕	RE

Then the newly added field will be shown as follows.

	ECTID 🔻 =	ε								
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
5	135	135	Home Garden		Home Garden		1572.0575592	. 29012.700455	Recreational	NULL
36	136	136	Home Garden		Residential		183.41696887	. 2127.5125698	Residential	NULL
37	137	137	Agriculture		Agricultural L		406.27829373	5088.6080518	Agricultural	NULL
38	138	138	Agriculture		Agricultural L		749.24850333	. 14046.275678	Agricultural	NULL
19	139	139	Other Road		Other Road		268.63809295	. 393.79835570	Transportation	NULL
40	140	140	Other Road		Other Road		3151.2409962	4716.2478129	Transportation	NULL
1	141	141	Other Road		Other Road		7927.2279571	. 11876.892761	Transportation	NULL
12	142	142	Other Road		Other Road		5305.7305048	. 7942.2790886	Transportation	NULL
43	143	143	Other Road		Other Road		835.45983964	. 1243.4290179	Transportation	NULL
44	144	144	Other Road		Other Road		341.85531339	. 503.59954561	Transportation	NULL
45	145	145	Other Road		Other Road		1587.9240328	. 2372.2912603	Transportation	NULL
46	146	146	Other Road		Other Road		32.405073394	. 39.174135890	Transportation	NULL
1 7	147	147	Other Road		Other Road		200.62409456	. 291.89928029	Transportation	NULL
18	148	148	Other Road		Other Road		717.78431239	. 1067.3883965	Transportation	NULL
49	149	149	Other Road		Other Road		253.05794024	. 370.37823791	Transportation	NULL
50	150	150	Other Road		Other Road		1399.9173100	. 2085.2591467	Transportation	NULL
51	151	151	Other Road		Other Road		443.68163905	. 656.52328238	Transportation	NULL
52	152	152	LA Road		Other Road		8480.2876979	. 14821.312527	Transportation	NULL
53	153	153			Scrub		289.90123489	. 655.79645462	Vegetation	NULL
54	154	154	•		Scrub		440.70526926	. 1423.6105749	Vegetation	NULL
55	155	155	Water Bodies		Water Bodies		5401.3995401	. 37031.925701	Water Bodies	NULL
56	156	156	Water Bodies		Water Bodies		2249.6653069	. 11832.371254	Water Bodies	NULL
57	157	157	,		Scrub		1734.9003544	. 32224.807303	Vegetation	NULL
58	158	158	Paddy		Paddy		1405.6878182	. 89066.918467	Agricultural	NULL
59	159	159	Home Garden		Home Garden		1026.7610499	. 35470.893797	Recreational	NULL
60	160	160	Agriculture		Agricultural L		483.24900122	. 8626.2173244	Agricultural	NULL
61	161	161			Scrub		430.69756366	. 9251.0425208	Vegetation	NULL
52	162	162			Scrub		212.07968185	. 2336.3694521	Vegetation	NULL
	163	163			Scrub		179.65238398	. 2115.2978551	Vegetation	NULL

Now, we have to add the values into this new field. For that, we should filter each sensitivity class by land uses from the attribute table.

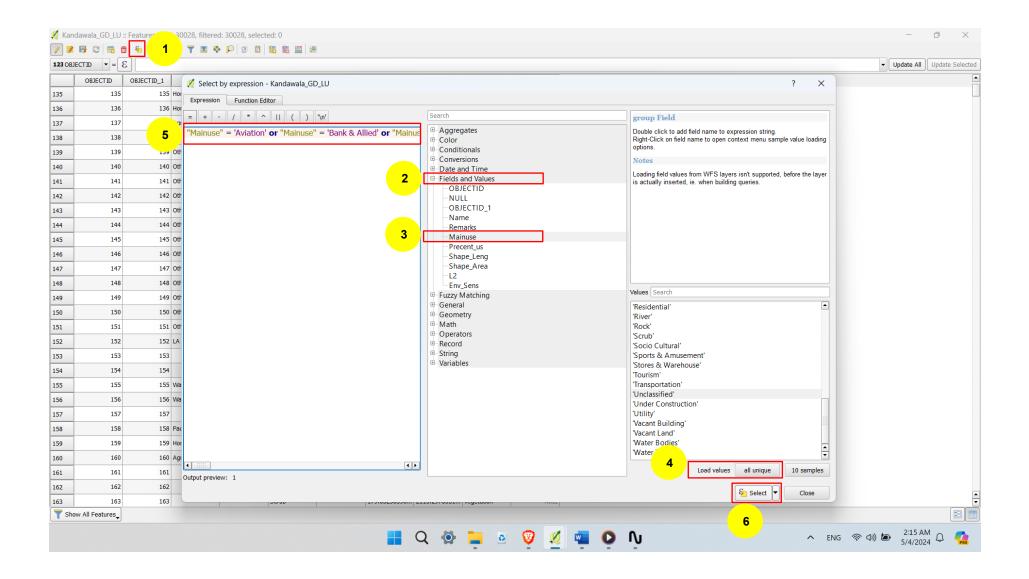
- 1. Open the "Select by the expression" as before mentioned way.
- 2. Expand the "Fields and Values".
- 3. Double-click on "Mainuse".
- 4. Click on "**all unique**". All the uniques under the "Mainuse" will be shown as follows.
- 5. Then, you have to enter the following expression on the expression tab. For that, double-click on "**Mainuse**", type "=", and double-click on the relevant land use category according to the sensitivity classes.

According to the above steps, first, select the land uses under the low sensitivity class. Once done entering a land use using this ["**Mainuse**" = 'Aviation'], type "or" and follow the same steps to add other land use categories into the expression. The "or" operator is used here to create a logical condition that selects features based on multiple criteria.

• So, add each land use continuously in this way,

"Mainuse" = 'Aviation' or "Mainuse" = 'Bank & Allied' or "Mainuse" = 'Commercial' or "Mainuse" = 'Educational'

After entering all land use categories into the expression using the above way, click on "Select".



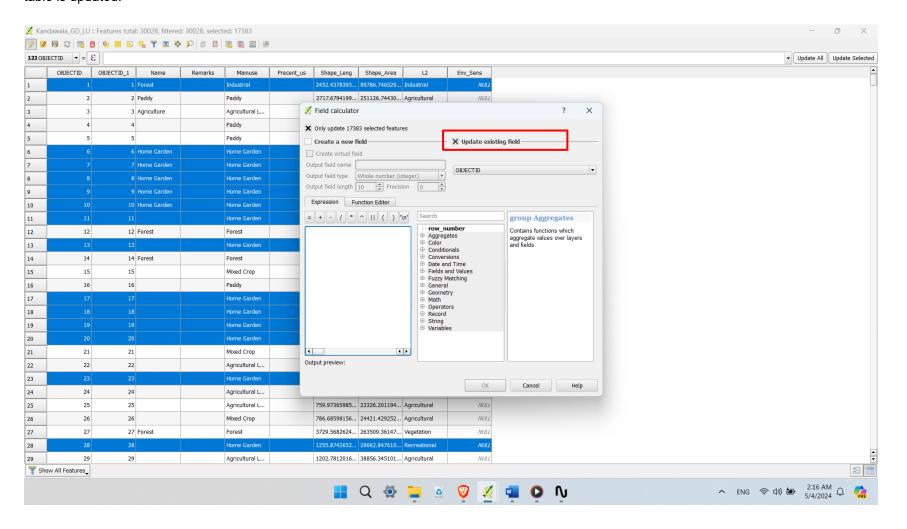
The selected data will be shown as follows.

	© 10 10 10 ▼ = [8		J 🔩 🕇 🏼 🤻								▼ Update All Upd
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens	
	1		1 Forest		Industrial	-		99786.746529		– NULL	
	2		2 Paddy		Paddy		2717.6794199	251126.74430	Agricultural	NULL	
	3		3 Agriculture		Agricultural L		4929.1831197	291030.99595	Agricultural	NULL	
	4		4		Paddy		1689.1721519	46418.289935	Agricultural	NULL	
	5		5		Paddy		2364.4199710	86727.679054	Agricultural	NULL	
	6		6 Home Garden		Home Garden		814.63028272	37431.211725	Recreational	NULL	
			7 Home Garden		Home Garden		919.44471945	. 38852.270967	Recreational	NULL	
	8		8 Home Garden		Home Garden		1713.6064177	. 128459.21254	Recreational	NULL	
			9 Home Garden		Home Garden		935.08365697	. 47755.462312	Recreational	NULL	
			.0 Home Garden		Home Garden		1118.6120919	. 24640.226392	Recreational	NULL	
	11	1	1		Home Garden		1201.2865415	23049.342736	Recreational	NULL	
	12	1	2 Forest		Forest		21616.107798	10599354.302	Vegetation	NULL	
	13	1	.3		Home Garden		852.31742858	18421.476763	Recreational	NULL	
	14	1	4 Forest		Forest		17135.849144	5175386.4355	Vegetation	NULL	
	15	1	.5		Mixed Crop			32271.862950	-	NULL	
	16		.6		Paddy		1350.5142022	57605.559316	Agricultural	NULL	
					Home Garden			79789.010855		NULL	
	18				Home Garden			138862.12720		NULL	
					Home Garden			67613.259116		NULL	
	20		20		Home Garden			58704.000606		NULL	
	21		21		Mixed Crop			40951.253578	-	NULL	
	22		2		Agricultural L			79753.400557	-	NULL	
	23		23		Home Garden			49153.841875		NULL	
	24		24		Agricultural L			23770.604646	-	NULL	
	25		25		Agricultural L			23326.201194	-	NULL	
	26 27		16		Mixed Crop			24421.429252	-	NULL	
	27		Prorest		Forest Home Garden			263509.36147 29062.847610	-	NULL	
	28		19		Agricultural L			38856.345101		NULL	
w A	ll Features	2			Ayricultur ar L		1202.7012010	30030.343101	Agricultural	NULL	
										Ø	▲ ENG 令 句) 細 2:15 AM 5/4/2024

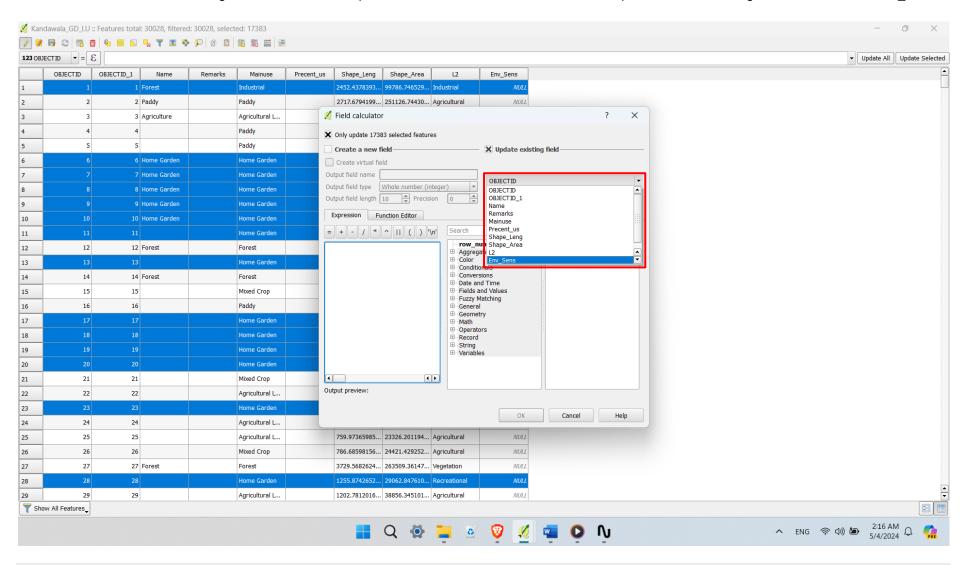
In the next step, we have to add the value for the "Env_Sens" column. According to the above steps, we selected here the **low-sensitive land use categories** and we assigned the value "**1**" for this sensitive class. For that, click on the icon for "**Open field calculator**".

BJB	ECTID - E				n field calculator	(Ctrl+I)					▼ Update All	Update
T	OBJECTID OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens			<u> </u>
ſ	1	1 Forest		Industrial		2452.4378393			NULL			
	2	2 Paddy		Paddy		2717.6794199	251126.74430	. Agricultural	NULL			
	3	3 Agriculture		Agricultural L		4929.1831197	291030.99595	. Agricultural	NULL			
	4	4		Paddy		1689.1721519	46418.289935	Agricultural	NULL			
	5	5		Paddy		2364.4199710	86727.679054	. Agricultural	NULL			
	6	6 Home Garden		Home Garden		814.63028272	37431.211725	Recreational	NULL			
		7 Home Garden		Home Garden		919.44471945	38852.270967	Recreational	NULL			
		8 Home Garden		Home Garden		1713.6064177	128459.21254	Recreational	NULL			
		9 Home Garden		Home Garden		935.08365697	47755.462312	. Recreational	NULL			
		10 Home Garden		Home Garden		1118.6120919	24640.226392	. Recreational	NULL			
		11		Home Garden		1201.2865415	23049.342736	Recreational	NULL			
	12	12 Forest		Forest		21616.107798	10599354.302	. Vegetation	NULL			
	13	13		Home Garden		852.31742858	18421.476763	. Recreational	NULL			
	14	14 Forest		Forest		17135.849144	5175386.4355	. Vegetation	NULL			
	15	15		Mixed Crop		1137.0831688	32271.862950	. Agricultural	NULL			
	16	16		Paddy		1350.5142022	57605.559316	. Agricultural	NULL			
		17		Home Garden		1845.3138304	79789.010855	. Recreational	NULL			
	18	18		Home Garden		1733.7183385	138862.12720	. Recreational	NULL			
	19	19		Home Garden		1445.5148543	67613.259116	Recreational	NULL			
ļ	20	20		Home Garden		2270.1932606	58704.000606	. Recreational	NULL			
	21	21		Mixed Crop		1326.4450168	40951.253578	. Agricultural	NULL			
	22	22		Agricultural L		1969.5597131	79753.400557	. Agricultural	NULL			
	23	23		Home Garden		1113.2412928	49153.841875	. Recreational	NULL			
	24	24		Agricultural L		783.91632547	23770.604646	. Agricultural	NULL			
	25	25		Agricultural L		759.97365985	23326.201194	Agricultural	NULL			
Ĺ	26	26		Mixed Crop		786.68598156	24421.429252	. Agricultural	NULL			
	27	27 Forest		Forest		3729.5682624	263509.36147	Vegetation	NULL			
	28	28		Home Garden		1255.8742652	29062.847610	Recreational	NULL			
		29		Agricultural L		1202.7812016	38856.345101	Agricultural	NULL		 	
	v All Features											

The field calculator will open. Click on the "**Update existing field**" and make sure to display the "×" mark on that. Through this, an existing field in the attribute table is updated.



Now, we have to select the existing field that we want to update. For that, click on "OBJECTID" and expand it to the following fields. Then select "Env_Sens".

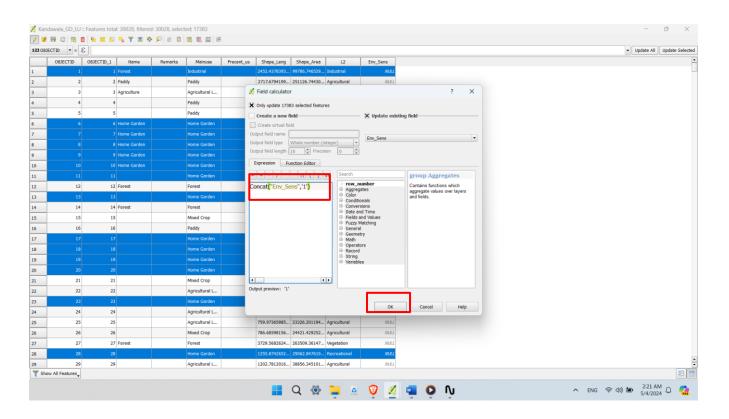


After selecting the field, you can use the following expression to add "1" to the selected field at once. Then the sensitivity of all the low-sensitive land use categories we selected above will be updated as "1" on the attribute table.

• Once done entering this expression, you can click on "OK" to proceed. This expression contains,

Concat ("Name of the existing field", 'The value')

• You should correctly type this expression using single commas and double commas. If you do not enter this correctly, you will have an error message.



Now, the values are added to the attribute table.

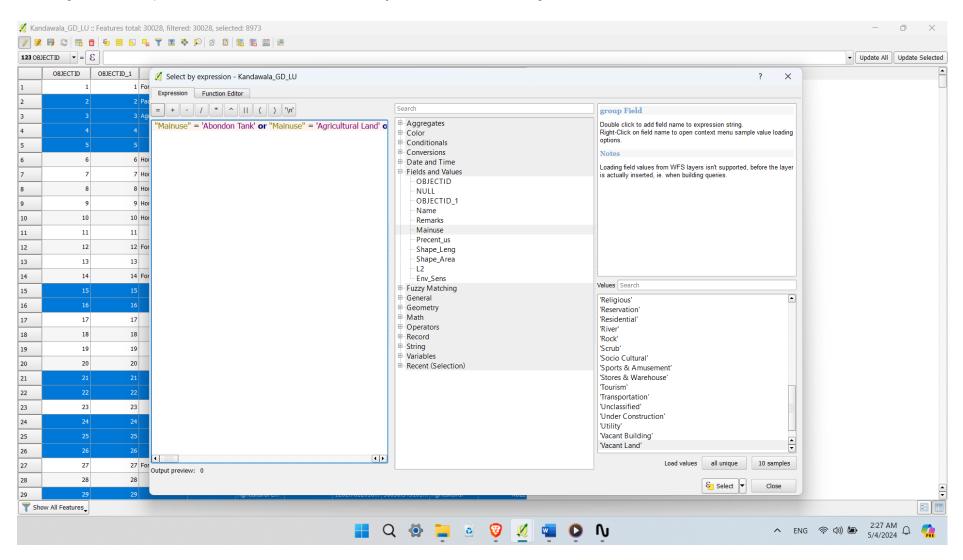
	ID ▼ = {		1	1	1		1	1	1	1	▼ Update All Up
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens	
	1		Forest		Industrial			99786.746529		NULL	
_	2		Paddy Agriculture		Paddy Agricultural L			251126.74430 291030.99595		NULL	
-	4	4	-		Paddy			46418.289935	-	NULL	
	5	5			Paddy			86727.679054	-	NULL	
	6		Home Garden		Home Garden			37431.211725	-	1	
			Home Garden		Home Garden			38852.270967		1	
			Home Garden		Home Garden			128459.21254		1	
		9	Home Garden		Home Garden		935.08365697	47755.462312	Recreational	1	
		10	Home Garden		Home Garden		1118.6120919	24640.226392	Recreational	1	
					Home Garden		1201.2865415	23049.342736	Recreational	1	
	12	12	Forest		Forest		21616.107798	10599354.302	Vegetation	NULL	
	13	13			Home Garden		852.31742858	18421.476763	Recreational	1	
	14	14	Forest		Forest		17135.849144	5175386.4355	Vegetation	NULL	
	15	15	;		Mixed Crop		1137.0831688	32271.862950	Agricultural	NULL	
	16	16	6		Paddy		1350.5142022	57605.559316	Agricultural	NULL	
					Home Garden		1845.3138304	79789.010855	Recreational	1	
	18	18			Home Garden		1733.7183385	138862.12720	Recreational	1	
					Home Garden			67613.259116		1	
	20				Home Garden			58704.000606		1	
	21	21			Mixed Crop			40951.253578	-	NULL	
	22	22			Agricultural L			79753.400557		NULL	
	23				Home Garden			49153.841875		1	
	24	24			Agricultural L			23770.604646	-	NULL	
	25	25	-		Agricultural L			23326.201194	-	NULL	
_	26 27	26	/ Forest		Mixed Crop Forest			24421.429252 263509.36147		NULL	
	27				Home Garden			29062.847610		INULL	
	28	20			Agricultural L			38856.345101		NULL	
Show	All Features	23	1		Agricultural E		1202.7812010	38830.343101	Agricultural	WOLL	

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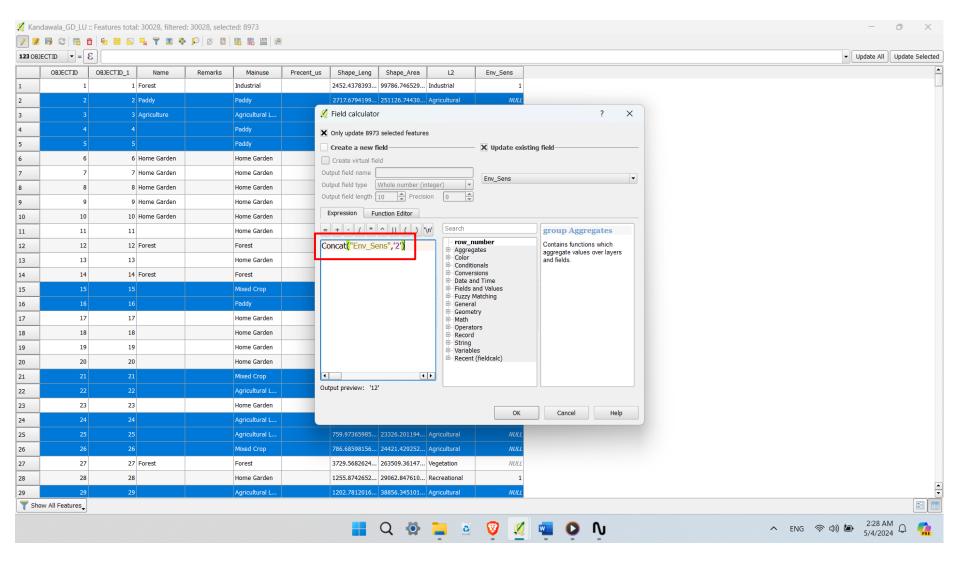
You can deselect these all features using the below tool.

			tal: 30028, filtere								- 0
	时 😂 1 📆 🚺 СТІР 🔍 = 🕻					9					▼ Update All Up
	OBJECTID	OBJECTID_1		(Ctrl+Shift+A) Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens	
	1	_	1 Forest	Kemarka	Industrial	Trecenc_us		99786.746529		Liv_Sens	
	2		2 Paddy		Paddy			. 251126.74430		NULL	
	3		3 Agriculture		Agricultural L			. 291030.99595		NULL	
	4		4		Paddy		1689.1721519	46418.289935	Agricultural	NULL	
	5		5		Paddy		2364.4199710	86727.679054	Agricultural	NULL	
	6		6 Home Garden		Home Garden		814.63028272	37431.211725	Recreational	1	
	7		7 Home Garden		Home Garden		919.44471945	. 38852.270967	Recreational	1	
	8		8 Home Garden		Home Garden		1713.6064177	. 128459.21254	Recreational	1	
	9		9 Home Garden		Home Garden		935.08365697	47755.462312	Recreational	1	
	10		0 Home Garden		Home Garden		1118.6120919	. 24640.226392	Recreational	1	
	11	1	1		Home Garden		1201.2865415	23049.342736	Recreational	1	
	12	1	2 Forest		Forest		21616.107798	10599354.302	Vegetation	NULL	
	13	1	13		Home Garden		852.31742858	. 18421.476763	Recreational	1	
	14	1	4 Forest		Forest		17135.849144	5175386.4355	Vegetation	NULL	
	15	1	.5		Mixed Crop		1137.0831688	32271.862950	Agricultural	NULL	
	16	1	.6		Paddy		1350.5142022	57605.559316	Agricultural	NULL	
	17				Home Garden		1845.3138304	79789.010855	Recreational	1	
	18				Home Garden		1733.7183385	. 138862.12720	Recreational	1	
	19				Home Garden		1445.5148543	67613.259116	Recreational	1	
	20	2	20		Home Garden		2270.1932606	. 58704.000606	Recreational	1	
	21	2	21		Mixed Crop		1326.4450168	40951.253578	Agricultural	NULL	
	22		22		Agricultural L			79753.400557	-	NULL	
	23		23		Home Garden			49153.841875		1	
	24		24		Agricultural L			23770.604646	-	NULL	
	25		25		Agricultural L			23326.201194		NULL	
	26		26		Mixed Crop			. 24421.429252		NULL	
	27		7 Forest		Forest			263509.36147		NULL	
_	28		28		Home Garden			29062.847610		1	
Charr	29 / All Features_	2	9		Agricultural L		1202.7812016	38856.345101	Agricultural	NULL	
SHOW	· / ··· reatures ▼										

Following the same steps, select the medium environmentally sensitive land use categories as follows.



After selecting these, again open the field calculator and update the existing field as follows. Use the expression here as, Concat ("Env_Sens", '2').



		<u> </u>								
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
	1		Forest		Industrial			99786.746529		1
_			Paddy		Paddy			251126.74430		2
			3 Agriculture		Agricultural L			291030.99595		2
					Paddy			46418.289935		2
	5		5		Paddy			86727.679054		2
	6		i Home Garden		Home Garden			37431.211725		1
	7		Home Garden		Home Garden			38852.270967		1
	8		B Home Garden		Home Garden			128459.21254		1
_	9		Home Garden		Home Garden			47755.462312		1
	10		Home Garden		Home Garden			24640.226392		1
1	11				Home Garden			23049.342736		1
2	12		? Forest		Forest			10599354.302	-	NULL
3	13				Home Garden			18421.476763		1
1	14		Forest		Forest			5175386.4355	-	NULL
5	15				Mixed Crop			32271.862950		2
6	16				Paddy			57605.559316		2
7	17				Home Garden			79789.010855		1
3	18				Home Garden			138862.12720		1
•	19				Home Garden			67613.259116		1
	20				Home Garden			58704.000606		1
	21 22				Mixed Crop			40951.253578		2
2	22				Agricultural L Home Garden			79753.400557		2
_	23				Agricultural L			49153.841875 23770.604646		1
4 5	24				Agricultural L			23770.604646		2
5 6	25				Mixed Crop			24421.429252		2
7	20		7 Forest		Forest			263509.36147		2 NULL
, В	27				Home Garden			29062.847610	-	1
•	20				Agricultural L			38856.345101		
	All Features	23			Agricultur ur L		1202.0012010	30030.345101	- Agriculturul	2

The updated field can be seen as follows. The "Env_Sens" field of the selected features shows the value "2".

All that remains is to select the **highly environmentally sensitive** land uses here. As an easy process for that, first, select low and medium environmentally sensitive land uses through "Select by the expression". For this,

- 1. Double-click on "Fields and Values" and expand it.
- 2. Again, double-click on "Env_Sens". Then the "Env_Sens" will appear on the expression tab.
- 3. Click on "all unique" and see the uniques under "Env_Sens".
- 4. Use the same expression to select low and medium environmentally sensitive land uses, "Env_Sens" = 1 or "Env_Sens" = 2
- 5. Click on "Select".

💋 Kar	dawala_GD_LU ::	: Features total: 30	0028, filtered: 30028, selected: 0 🗖	\times
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123 OB	ECTID - E		Update Filtered Update St	elected
	OBJECTID	OBJECTID_1	🛿 Select by expression - Kandawala_GD_LU ? X	-
1	1	1 For	Expression Function Editor	
2	2	2 Pac		
3	3	3 Ag	"Env_Sens" = 1 or "Env_Sens" = 2 Aggregates Double click to add field name to expression string.	
4	4	4	B Color Right-Click on field name to open context menu sample value loading	
5	5	5	Conditionals Options. Options Notes	
6	6	6 Hor	B-Date and Time	
7	7	7 Ho	Fields and Values Loading field values from WFS layers isn's upported, before the layer is actually inserted, ie. when building queries.	
8	8	8 Ho	NULL	
9	9	9 Ho	- OBJECTID_1 - Name	
10	10	10 Ho	- Remarks	
11	11	11	- Mainuse - Precent us	
12	12	12 For	-Shape_Leng	
13	13	13	-Shape Area	
14	14	14 For	- City_Selis	
15	15	15	Young Values Search Values Search Values Search Values	
16	16	16	Geometry	
17	17	17	Math Depertors Depertors	
18	18	18	₽ Record	
19	19	19	String Warables	
20	20	20	B Recent (Selection)	
21	21	21		
22	22	22		
23	23	23		
24	24	24	3	
25	25	25		
26	26	26		
27	27	27 For	Load values all unique 10 samples	
28	28	28	Select Cose	
29	29	29		-
T Sh	w Selected Featur	res_		3 📰
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OBJ	ECTID 🔻 = {	E	Invert selection (C	trl+R)						
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens
			1 Forest		Industrial		2452.4378393	99786.746529	Industrial	1
			2 Paddy		Paddy		2717.6794199	251126.74430	Agricultural	2
			3 Agriculture		Agricultural L		4929.1831197	291030.99595	Agricultural	2
			4		Paddy		1689.1721519	46418.289935	Agricultural	2
			5		Paddy		2364.4199710	86727.679054	Agricultural	2
			6 Home Garden		Home Garden		814.63028272	37431.211725	Recreational	1
			7 Home Garden		Home Garden		919.44471945	38852.270967	Recreational	1
	8		8 Home Garden		Home Garden		1713.6064177	128459.21254	Recreational	1
			9 Home Garden		Home Garden		935.08365697	47755.462312	Recreational	1
	10	1	0 Home Garden		Home Garden		1118.6120919	24640.226392	Recreational	1
			1		Home Garden		1201.2865415	23049.342736	Recreational	1
					Home Garden		852.31742858	18421.476763	Recreational	
	15		5		Mixed Crop		1137.0831688	32271.862950	Agricultural	2
	16	1	6		Paddy		1350.5142022	57605.559316	Agricultural	2
	17		7		Home Garden		1845.3138304	79789.010855	Recreational	
	18	1	8		Home Garden		1733.7183385	138862.12720	Recreational	
		1	9		Home Garden		1445.5148543	67613.259116	Recreational	
	20	2	0		Home Garden		2270.1932606	58704.000606	Recreational	
1					Mixed Crop		1326.4450168	40951.253578	Agricultural	2
1			2		Agricultural L		1969.5597131	79753.400557	Agricultural	2
ĺ					Home Garden		1113.2412928	49153.841875	Recreational	
	24	2	4		Agricultural L		783.91632547	23770.604646	Agricultural	2
	25	2	5		Agricultural L		759.97365985	23326.201194	Agricultural	2
	26	2	6		Mixed Crop		786.68598156	24421.429252	Agricultural	2
	28	2	8		Home Garden		1255.8742652	29062.847610	Recreational	
	29	2	9		Agricultural L		1202.7812016	38856.345101	Agricultural	2
	30	3	0		Agricultural L		1170.6508047	29991.599575	Agricultural	2
					Home Garden		2558.1216699	161627.09500	Recreational	
			2		Home Garden		1345.8739914	96050.060521	Recreational	
Sho	w Selected Featu	res								
								0 .	2	

Now, all the low and medium environmentally sensitive land uses are selected on the screen. But we want to select the highly sensitive land uses here. For that, click on the "**Invert selection**" tool.

🜠 Kandawala_GD_LU :: Features total: 30028, filtered: 4357, selected: 4357 O × _ 📝 😻 🕞 C 📅 🏛 省 ≡ 🔊 🔩 🍸 🍱 🏘 🔎 🚳 🛍 🛗 🚟 123 OBJECTID ▼ = 8 Update Filtered Update Selected OBJECTID OBJECTID_1 Shape_Leng Shape_Area L2 Env_Sens Remarks Mainuse Precent_us Name 1 12 21616.107798... 10599354.302... Vegetation 2 17135.849144... 5175386.4355... Vegetation 3 4 323.32348703... 1105.1990500... Vacant Lands Reservation 5 6 1192.0274945... 34065.180589... Vegetation 7 59 Water Bodies Water Bodies 3673.0555203... 43377.244213... Water Bodies 8 62 Water Bodies Water Bodies 1237.1178700... 60391.659559... Water Bodies 9 66 AB Paddy 10 2427.5770335... 122724.90334... Vegetation 11 70 Water Bodies Water Bodies 956.04417328... 33320.384899... Water Bodies 12 73 Water Bodies Water Bodies 2301.0283513... 143128.13297... Water Bodies 13 74 Water Bodies Water Bodies 765.27825109... 19852.947950... Water Bodies 14 10011.091495... 912704.61880... Vegetation 15 951.57278579... 43445.711205... Vegetation 16 82 Water Bodies Water Bodies 2346.9810982... 89242.974613... Water Bodies 17 18 938.87137734... 17118.627942... Vegetation 19 89 Water Bodies Water Bodies 218.33525510... 2510.0850996... Water Bodies 20 797.81814615... 16801.742987... Vegetation 21 96 Water Bodies Water Bodies 6162.9016011... 32326.407293... Water Bodies 22 682.47238271... 15293.238992... Agricultural 23 98 Forest Forest 24 612.20294069... 11556.814734... Vegetation 25 498.02319323... 4863.7076866... Vegetation 26 27 113 Water Bodies Water Bodies 2716.4134701... 26050.478615... Water Bodies 28 29 760.07638880... 11858.656855... Vegetation T Show Selected Features ヘ ENG 奈 Φ) 値 ^{2:37 AM} Ω 📘 Q 🚳 📜 🙆 🦁 💋 💶 🖸 N

Then, the highly sensitive land uses will be automatically selected on the screen.

Now, we can follow the same process to enter the values for these features. Open the field calculator and update the existing field using the expression,

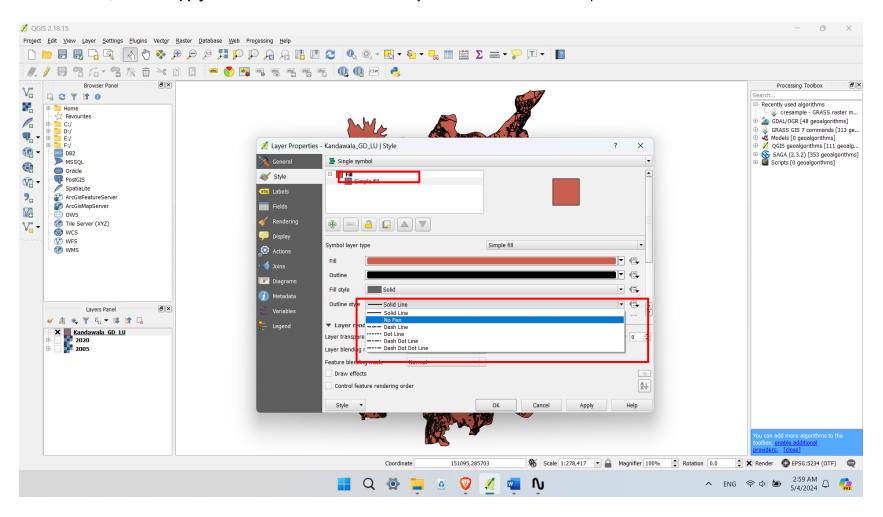
🌠 Ka	ndawala_GD_LU	J :: Features total: 30028, filter	red: 4357, selected: 4357		- 0 ×
1	1 🗟 🕄	💼 🗧 🗉 💊 🍸 🔳	🏘 🔎 🗈 🖬 🌆 🗃		
1230	BJECTID 🔻 =	3			Update Filtered Update Selected
	OBJECTID	OBJECTID_1 Name	Remarks Mainuse	Precent_us Shape_Leng Shape_Area L2 Env_Sens	_
1	12	12 Forest	Forest	21616.107798 10599354.302 Vegetation	
2		14 Forest	Forest	17135.849144 5175386.4355 Vegetation	
3		27 Forest	Forest	🌠 Field calculator ? X	
4	38	38	Reservation	X Only update 4357 selected features	
5			Scrub	Create a new field X Update existing field	
6	46	46	Forest	Create virtual field	
7	59	59 Water Bodies	Water Bodies	Output field name Env_Sens	
8	62	62 Water Bodies	Water Bodies	Output field type Whole number (integer)	
9	66	66 AB Paddy	Forest	Output field length 10 \xrightarrow{A} Precision 0 \xrightarrow{A}	
10		67 Marshy	Marshy	Expression Function Editor	
11		70 Water Bodies	Water Bodies	= + - / * ^ II () '\n' Search group Aggregates	
12		73 Water Bodies	Water Bodies	Concat("Env_Sens",'3") Contains functions which aggregates aggregate values over layers	
13	74	74 Water Bodies	Water Bodies	B ⊂ Color and fields.	
14		76 Forest	Forest	B- Conversions B- Date and Time	
15			Forest	Fields and Values Fuzzy Matching	
16	82	82 Water Bodies	Water Bodies	E-General E-Geometry	
17	84	84	Forest	⊕ Math ⊕ Operators	
18	86	86	Scrub	B Record	
19	89	89 Water Bodies	Water Bodies	B - Variables	
20		92	Forest	B-Recent (fieldcalc)	
21	96		Water Bodies		
22			Chena	Output preview: '13'	
23	98		Forest	OK Cancel Help	
24	99		Scrub		
25	100		Scrub	498.02319323 4863.7076866 Vegetation	
26	102		Forest	686.36281690 21366.035025 Vegetation	
27			Water Bodies	2716.4134701 26050.478615 Water Bodies	
28			Residential	122.81017400 847.58659650 Residential	
29	116		Scrub	760.07638880 11858.656855 Vegetation	
T S	how Selected Feat	tures			
				📕 Q 🏟 📜 🧕 🦁 💆 🖏 📭 🗘	ヘ ENG (奈 ゆ)) 🎦 ^{2:37} AM 💭 🇖

Concat ("Env_Sens", '3').

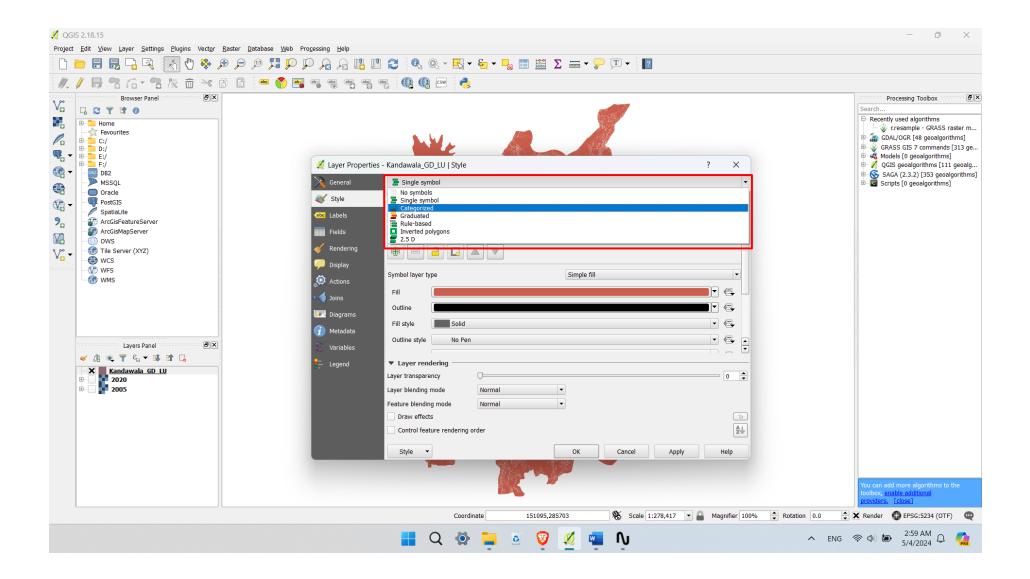
After adding these values successfully, click on the pencil icon again and save the edits.

	IECTID 🔻 =	3													-	Update Filter	ed
	OBJECTID	OBJECTID_1	Name	Remarks	Mainuse	Precent_us	Shape_Leng	Shape_Area	L2	Env_Sens							
	1	1 For	rest		Industrial		2452.4378393	99786.746529	. Industrial								
	2	2 Pac	ddy		Paddy		2717.6794199	251126.74430	. Agricultural		:						
	3	3 Agr	riculture		Agricultural L		4929.1831197	291030.99595	. Agricultural		:						
	4	4			Paddy		1689.1721519	46418.289935	. Agricultural		:						
	5	5			Paddy		2364.4199710	86727.679054	. Agricultural		:						
;	6	6 Hor	me Garden		Home Garden		814.63028272	37431.211725	. Recreational		1						
,	7	7 Hor	me Garden		Home Garden		919.44471945	38852.270967	. Recreational								
3	8	8 Hor	me Garden		Home Garden		1713.6064177	128459.21254	. Recreational								
)	9	9 Hor	me Garden		Home Garden		935.08365697	47755.462312	. Recreational								
10	10	10 Hor	me Garden		Home Garden		1118.6120919	24640.226392	. Recreational								
1	11	11			Home Garden		1201.286 🛒 S	top editing				×					
12	12	12 For	rest		Forest		21616.10	Do vou wa	ant to save the	changes to lave	r Kandawala_GD	LU?					
13	13	13			Home Garden		852.3174										
14	14	14 For	rest		Forest		17135.84	s	ave [Discard	ancel						
15	15	15			Mixed Crop		1137.0831000	322/1.002930	. Agriculturai								
.6	16	16			Paddy		1350.5142022	57605.559316	. Agricultural								
7	17	17			Home Garden		1845.3138304	79789.010855	. Recreational								
.8	18	18			Home Garden		1733.7183385	138862.12720	. Recreational								
9	19	19			Home Garden		1445.5148543	67613.259116	. Recreational								
0	20	20			Home Garden		2270.1932606	58704.000606	. Recreational								
21	21	21			Mixed Crop		1326.4450168	40951.253578	. Agricultural		1						
22	22	22			Agricultural L		1969.5597131	79753.400557	. Agricultural		1						
23	23	23			Home Garden		1113.2412928	49153.841875	. Recreational		.]						
24	24	24			Agricultural L		783.91632547	23770.604646	. Agricultural		1						
25	25	25			Agricultural L		759.97365985	23326.201194	. Agricultural		2						
26	26	26			Mixed Crop		786.68598156	24421.429252	. Agricultural		Î.						
27	27	27 For	rest		Forest		3729.5682624	263509.36147	. Vegetation		1						
28	28	28			Home Garden		1255.8742652	29062.847610	. Recreational		[
_	29	29			Agricultural L		1202.7812016	38856.345101	Agricultural		1						

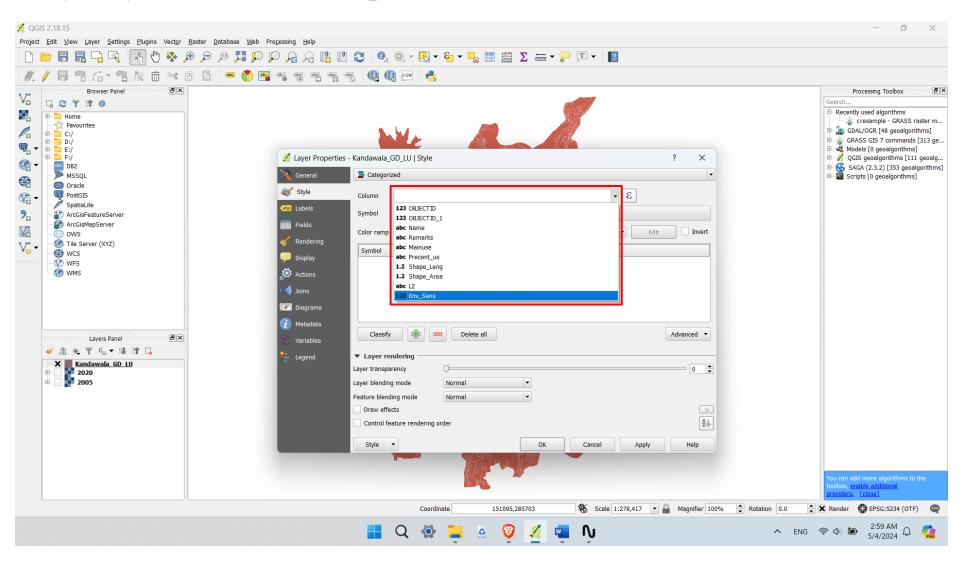
After saving the edits, open the layer properties and go to the "**Style properties**". Next, click on "**Simple fill**". Then expand the "**Outline style**" and select "**No Pen**". After that, click on "**Apply**" and "**OK**". Outlines of the vector layer will be removed from this process.



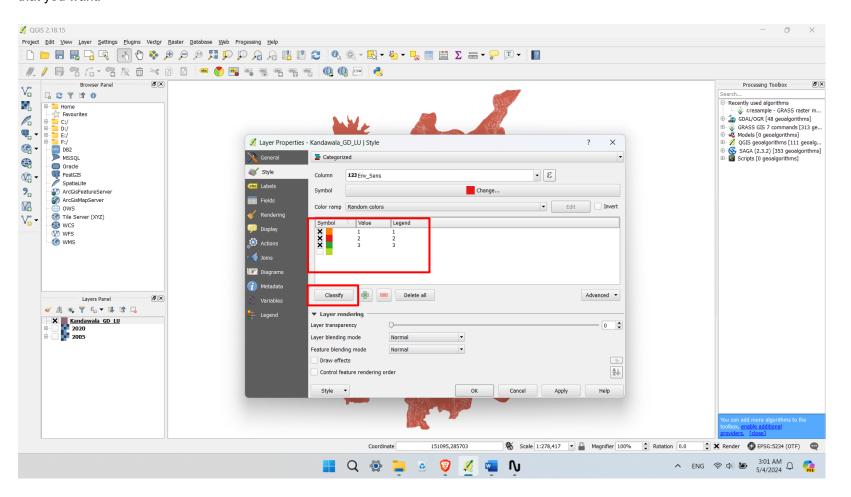
Let's categorize this vector layer. For that, click on "Single symbol" and expand it. Select "Categorized" from the expanded list.



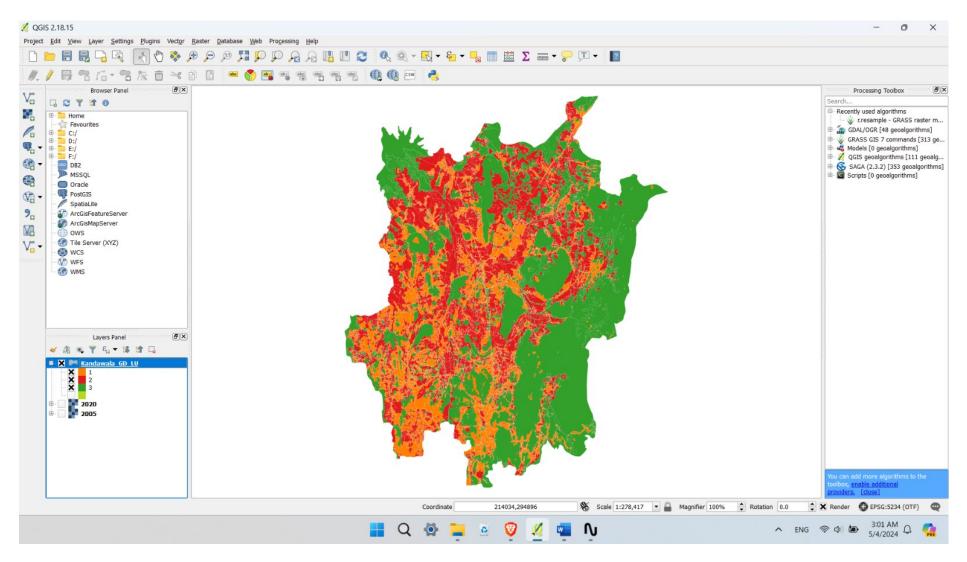
Next, expand the option "Column", and select the field "Env_Sens".



Click on "**Classify**", then the classification will be displayed as follows. If you want to change the colors of each category, click on the color and select the color that you want.



Here is the classification according to the environmental sensitivity of the Dambulla region.



Next, we have to check the coordinate reference system and other requirements as the above land use layers. First, check the coordinate reference system as follows. If it is not match with the above land use layers, take the necessary actions to change it.

🕺 Layer Properties	- Kandawala_GD_LU General	?	×
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(abc) Labels	Layer source 52\Module 03 - Land Use Planning in Dambulla\Shp files\Land Use - Greater Dambulla\Kandawa Data source encoding System	a_GD_LU.S	np
🞸 Rendering 戸 Display	▼ Coordinate reference system Selected CRS (EPSG:5234, Kandawala / Sri Lanka Grid)	•	2
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阿 Diagrams 🥡 Metadata	Minimum (exclusive) Maximum (inclusive)	•	
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And as before, this vector layer needs to be converted into a raster layer. After that, if the cell size, rows, and column values are not the same, the resampling process has to be done. In this way, you can prepare the layer for the environmental sensitivity of the Dambulla area.

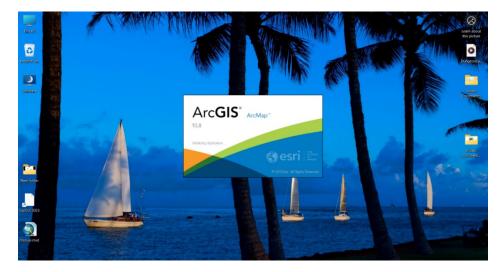
2. Road Density

Road density plays a pivotal role and can significantly influence land use patterns. Road density is a vital factor in land use simulation due to its profound influence on economic activity, urban expansion, environmental sustainability, and public service provision. By incorporating road density into land use models, planners, and policymakers can make more informed decisions that balance development needs with environmental and social considerations. This holistic approach ensures that land use planning supports sustainable and resilient urban and rural development.

Initially, this book was developed using QGIS, an open-source GIS software. However, we have now transitioned to using ArcMap, which is not open source. The reason for this change is that QGIS cannot easily create road density layers, whereas ArcMap offers advanced tools that make this process straightforward and efficient. This adjustment ensures that the book remains practical and effective for users needing detailed road density analysis in their land use simulations.

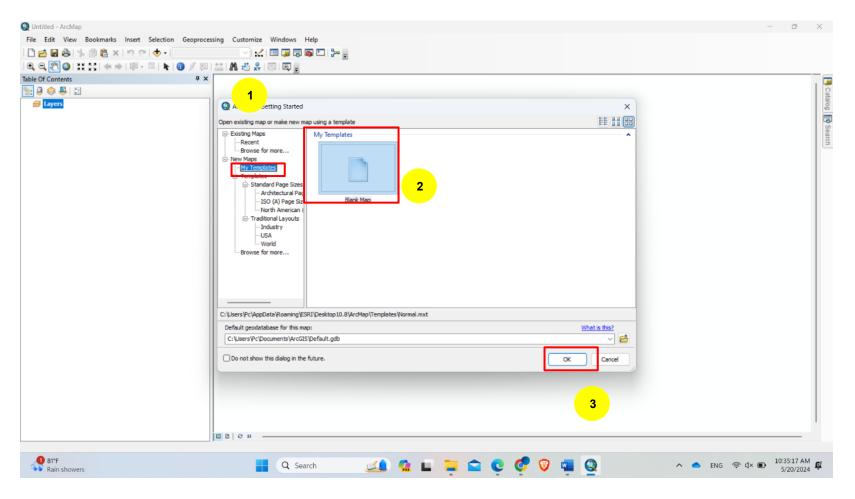
1. Opening ArcMap

To create this layer, first, open Arc Map software.



Starting a New Map

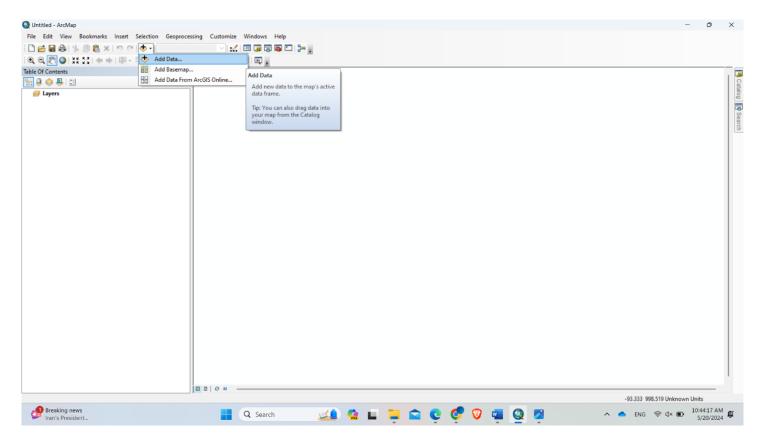
In the ArcMap startup dialog box, you can choose to open an existing map or start a new one. To create a new map, select "Blank Map" from "My Templates" and click "OK". This will open a blank map document where you can add and work with spatial data.



2. Adding a Shapefile

To add a shapefile, first ensure that your shapefile (.shp) and its associated files (.shx, .dbf, etc.) are saved in an accessible directory on your computer.

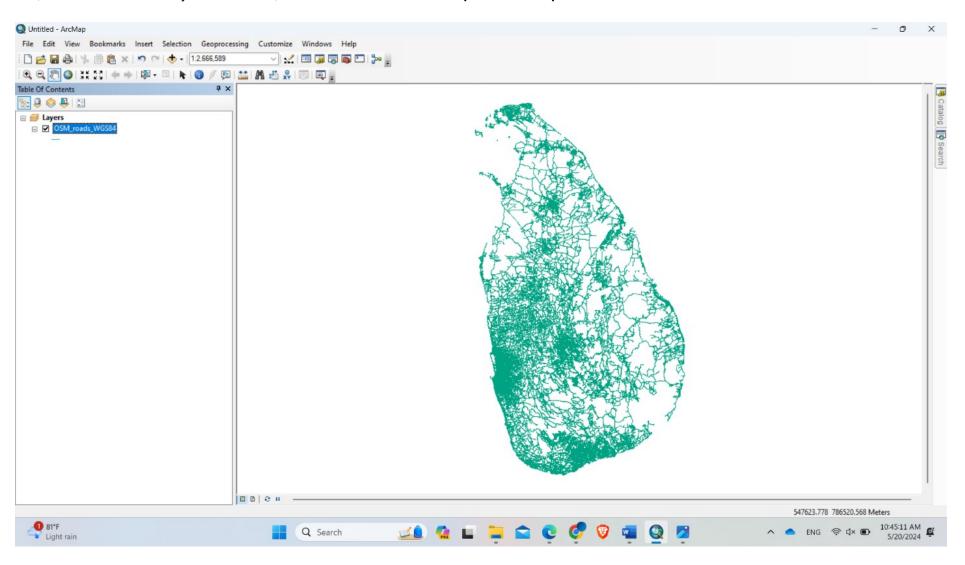
In ArcMap, go to the "File" menu and select "Add Data". Alternatively, you can click the "Add Data" button (represented by a plus sign icon) on the Standard toolbar.

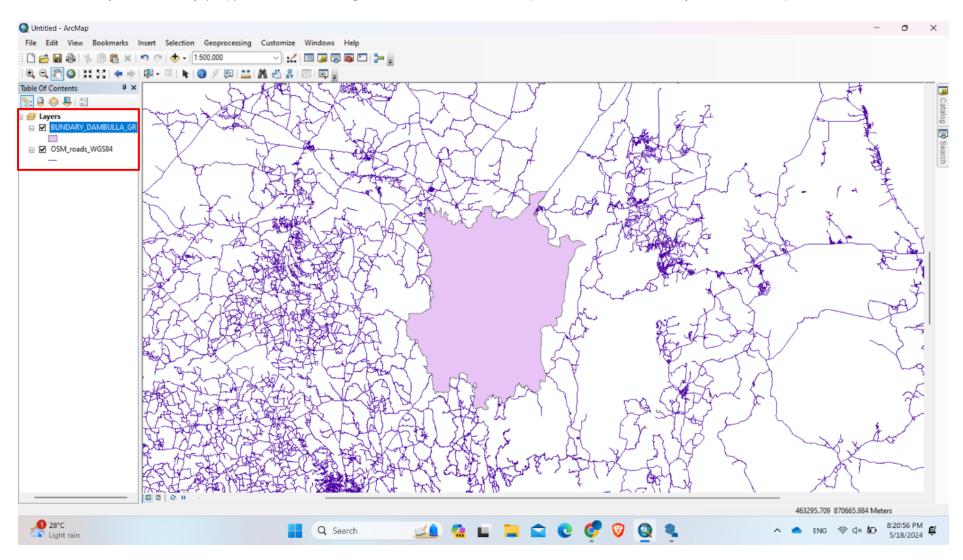


In the Add Data dialog box, navigate to the location of your shapefile. Select the shapefile you wish to add and click "Add".

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The shapefile will now appear as a new layer in the Table of Contents on the left side of the ArcMap interface, and its data will be displayed on the map. For that, have added the road layer of Sri Lanka, which was downloaded from **Open Street Map**.

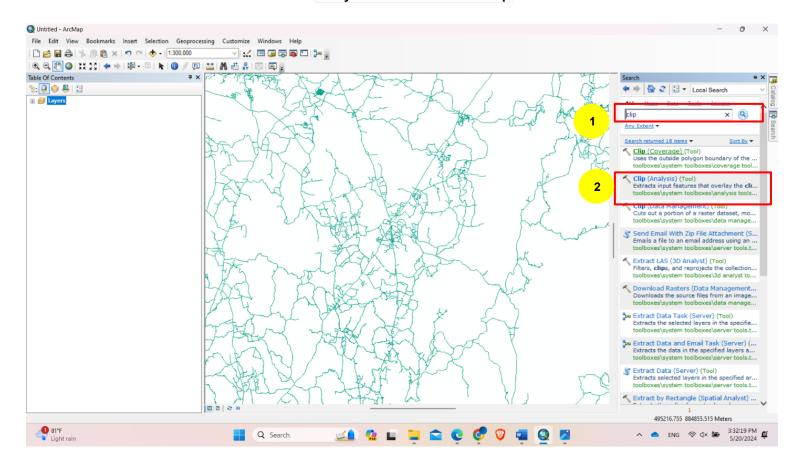




In the same way, the boundary (.shp) file created for the greater Dambulla area was imported. Now there are 2 layers in the workspace.

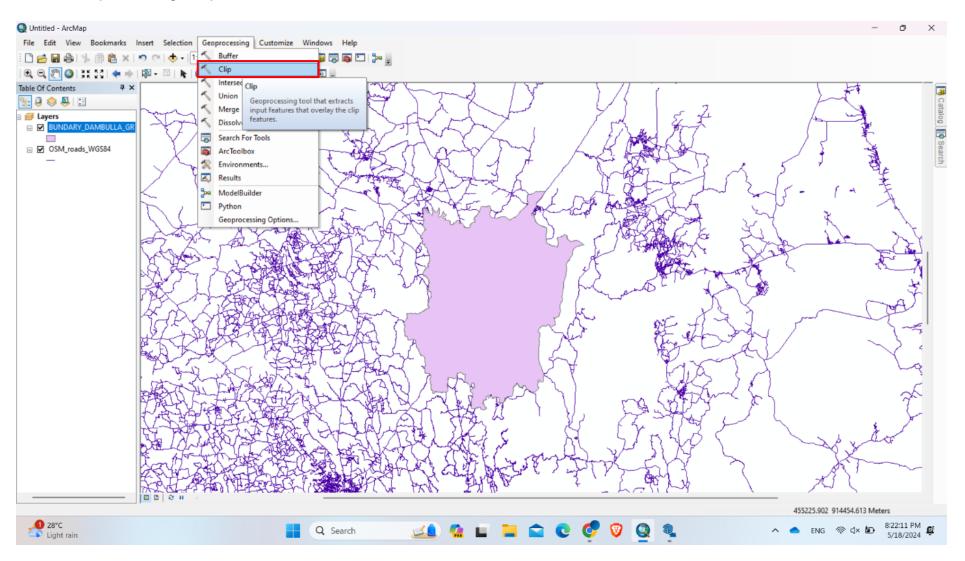
3. Run the Clip Tool.

Then use the clip tool to select the road layer only for the relevant area. Go to the "Geoprocessing" menu at the top of the ArcMap interface and select "Clip". Alternatively, you can search for the Clip tool in the "Search" window or access it through "ArcToolbox" by navigating to,



Analysis Tools > Extract > Clip.

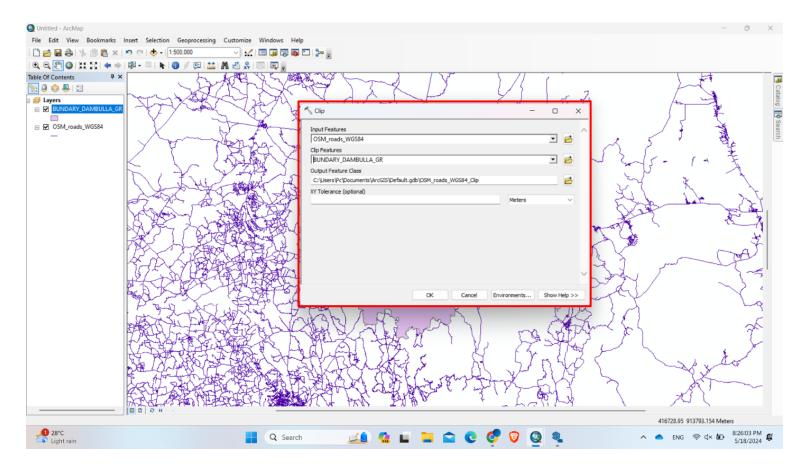
Or select Geoprossessing > Clip



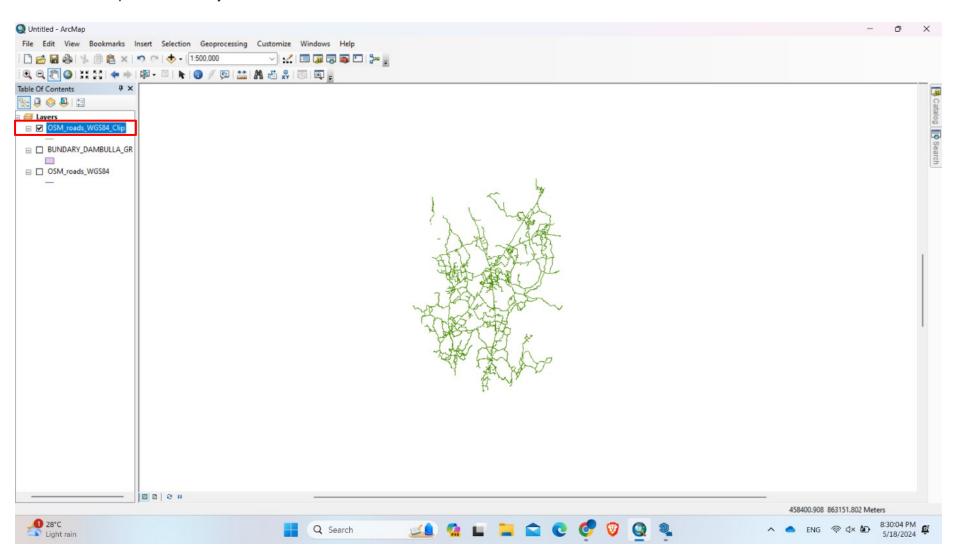
I. In the Clip tool dialog box, set the following parameters.

- II. Input Features: Select your road layer (the layer you want to clip).
- III. Clip Features: Select your boundary shapefile (the area you want to clip to).
- IV. **Output Feature Class:** Specify the location and name for the output clipped layer. Click the folder icon to navigate to the desired save location and provide a name for the new shapefile.

After setting the parameters, click "**OK**" to run the Clip tool. The tool will process the data and create a new clipped road layer based on the boundary you provided.

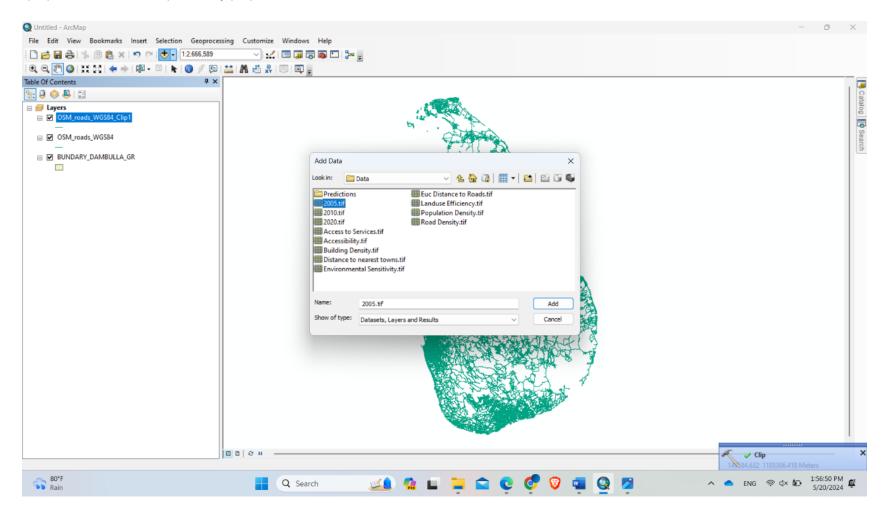


Once the Clip tool has finished running, the new clipped road layer will be added to your map. Review the output to ensure that it accurately represents the roads within the specified boundary area.

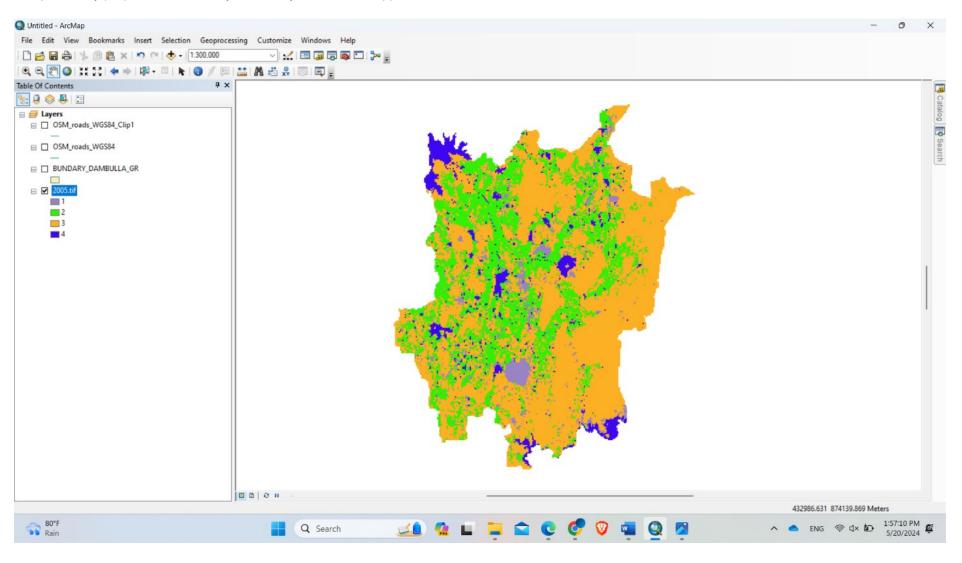


4. Adding a previously prepared correct raster file for the setup of new factors.

We need to ensure that the correct raster file is used because we follow the coordinate system, pixel size, and row and column configuration of this file. For this purpose, I have used a previously prepared 2005 Land use raster file.

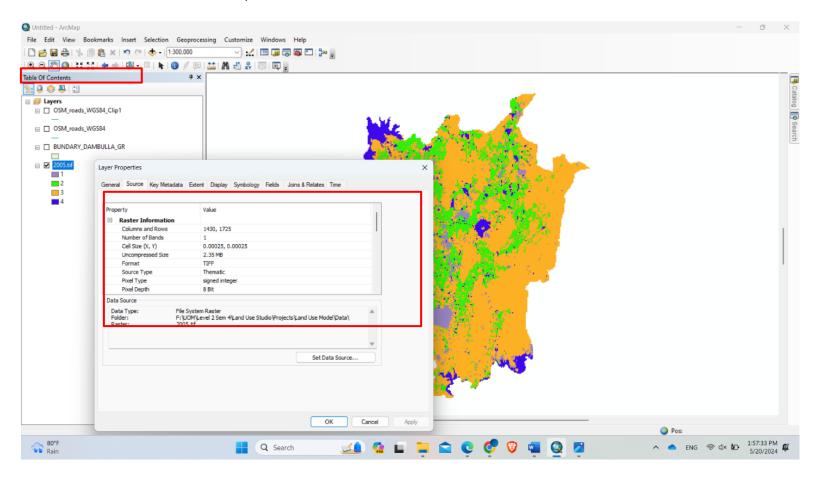


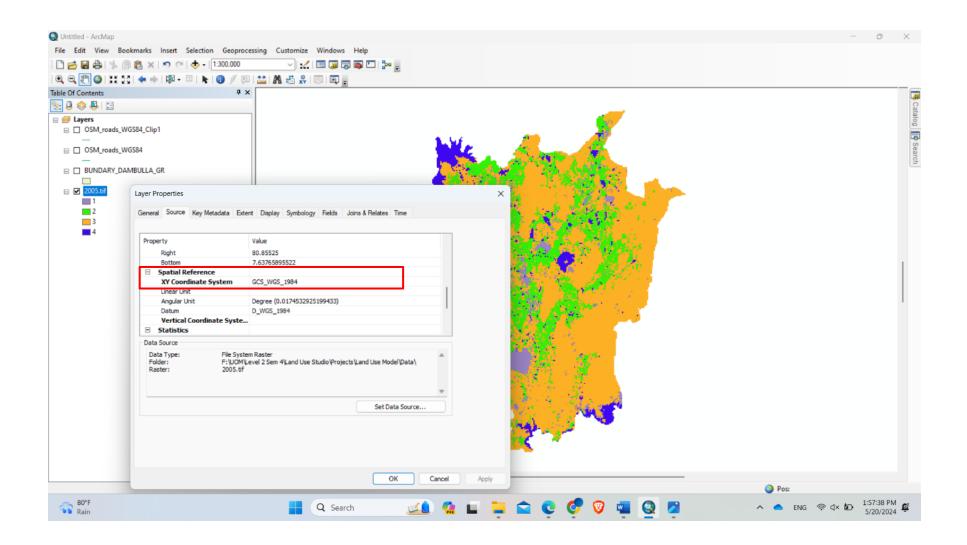
The previously prepared land use layer for the year 2005 will appear on the screen as follows.



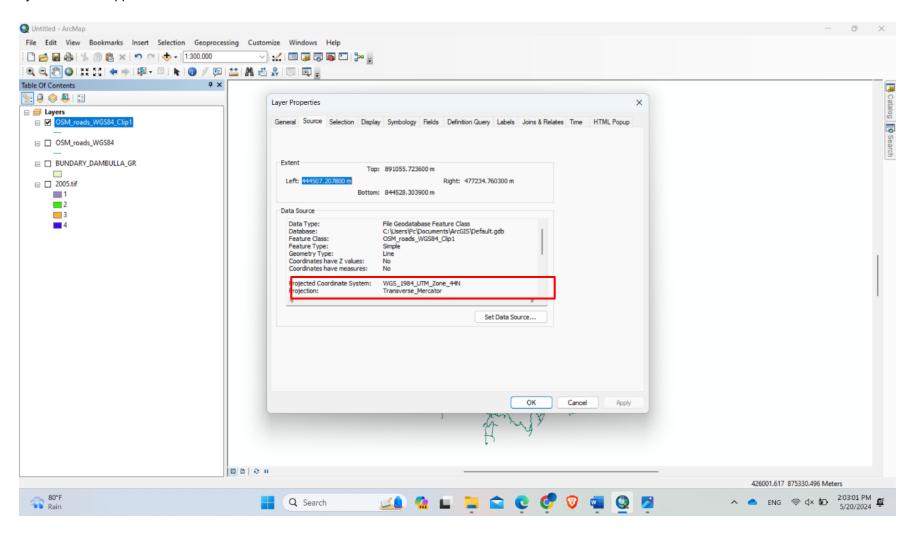
5. Ensure Consistent Coordinate Systems

- First, make sure that all your layers (road layer, boundary shapefile, and raster file) have the same coordinate system.
- Right-click each layer in the Table of Contents, select "**Properties**," then go to the "**Source**" tab to check the coordinate system.
- After that, checked and noted the pixel size and row columns of the 2005 land use raster file.



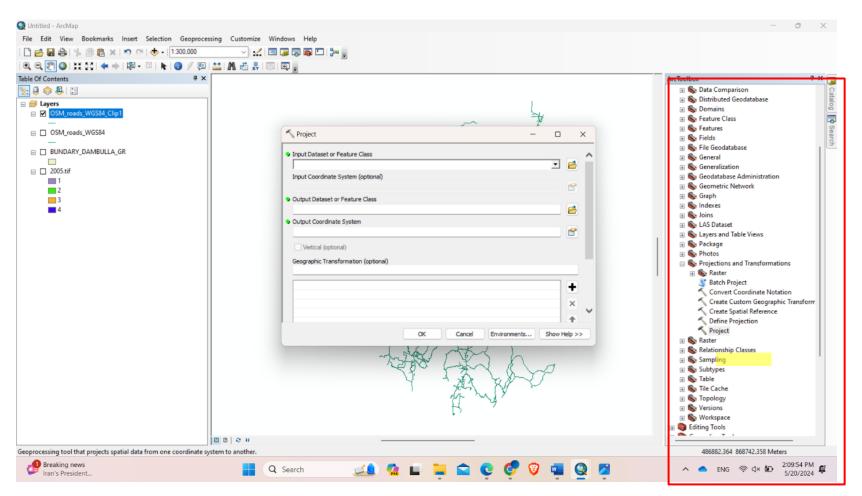


Upon examination, I observed discrepancies in the coordinate system of the clipped file. Consequently, I utilized the "**Project**" tool to rectify the coordinate system of the clipped file to match the desired one.



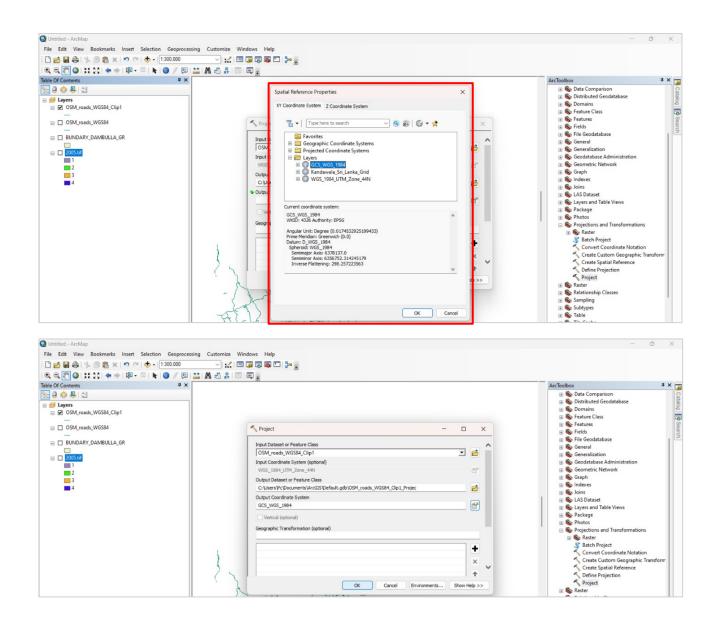
6. Project (.shp) file to the same coordinate system.

If any layers have different coordinate systems, you need to project them to the same coordinate system. You can use the "Project" tool found under,

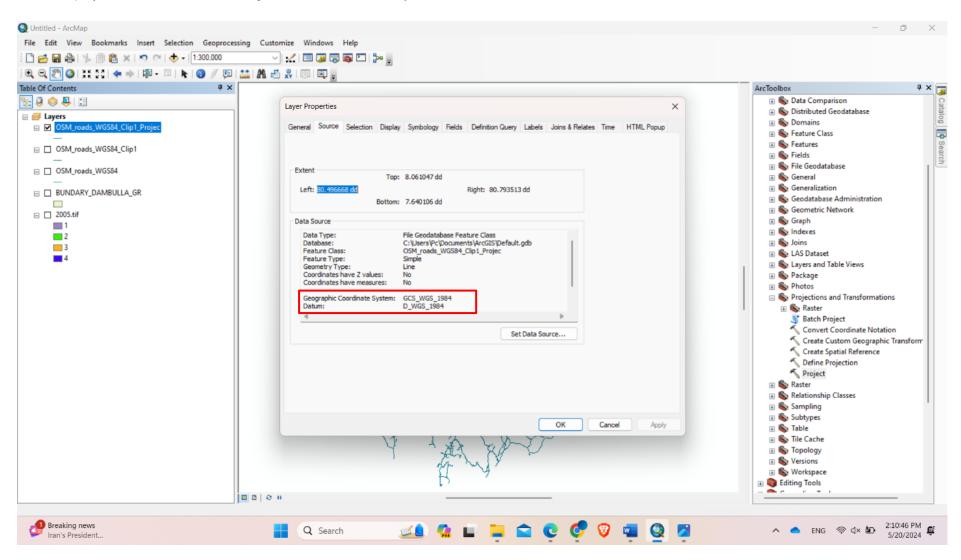


Arc Toolbox > Data Management Tools > Projections and Transformations > Project

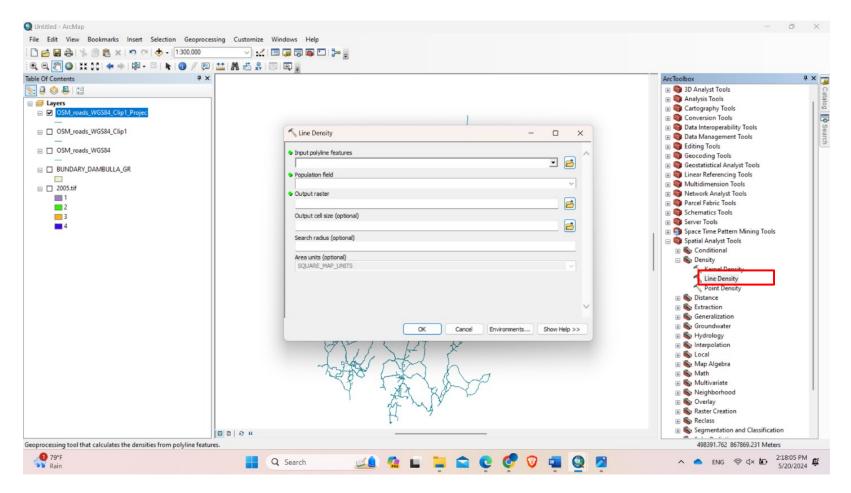
Select the Clipped Road layer to the Input Dataset or feature class and select 2005 Land use raster layers' coordinate system to coordinate system.



Once the project tool has finished running, check the coordinate system of the raster file.



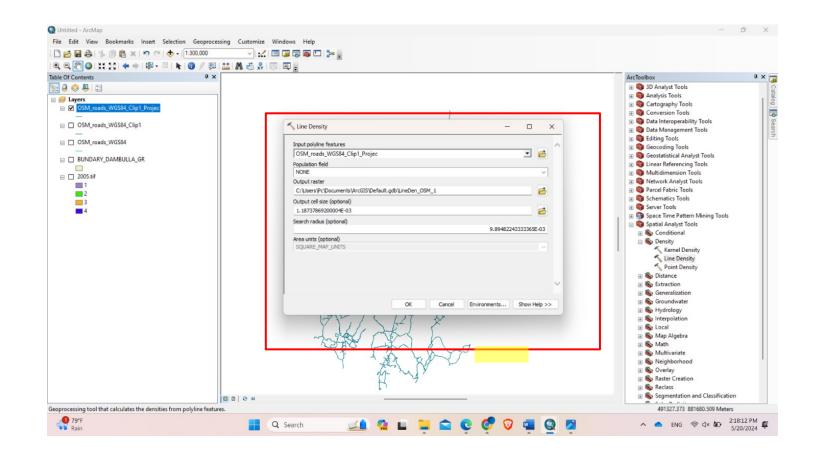
- 7. Open the Line Density Tool.
 - Go to "ArcToolbox" and navigate to Spatial Analyst Tools > Density > Line Density.
 - If "Spatial Analyst" is not enabled, you need to activate it by going to Customize > Extensions and checking "Spatial Analyst".



Set Line Density Tool Parameters

In the Line Density tool dialog box, set the following parameters:

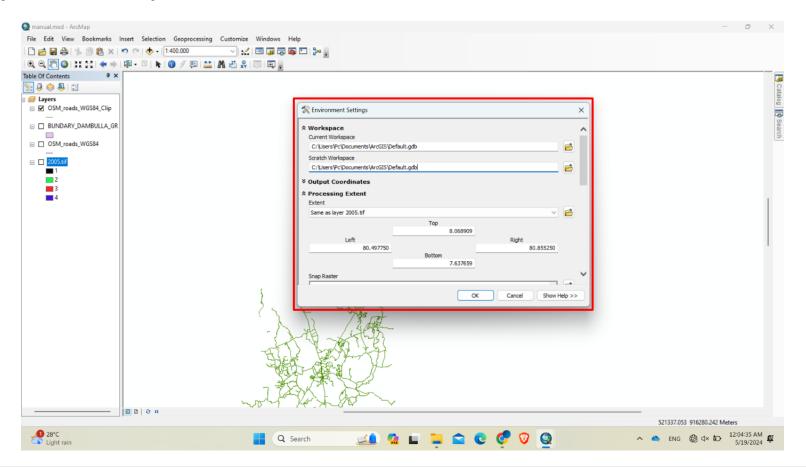
- I. Input Polyline Features: Select your correct road layer.
- II. Output Raster: Specify the location and name for the output raster file.



Adjusting Pixel Size and Aligning with Existing Raster

- I. If the output raster needs to match an existing raster's pixel size and alignment exactly, use the environment setting. Go to Environments.
- II. Then set up the workspace as the default workspace.
- III. Under "Raster Analysis," set the "Cell Size" to match your existing raster and set the "Mask" to match your existing raster.
- IV. Under "Processing Extent," set the "Extent" to your existing raster layer.

Then change the environment setting as follows.

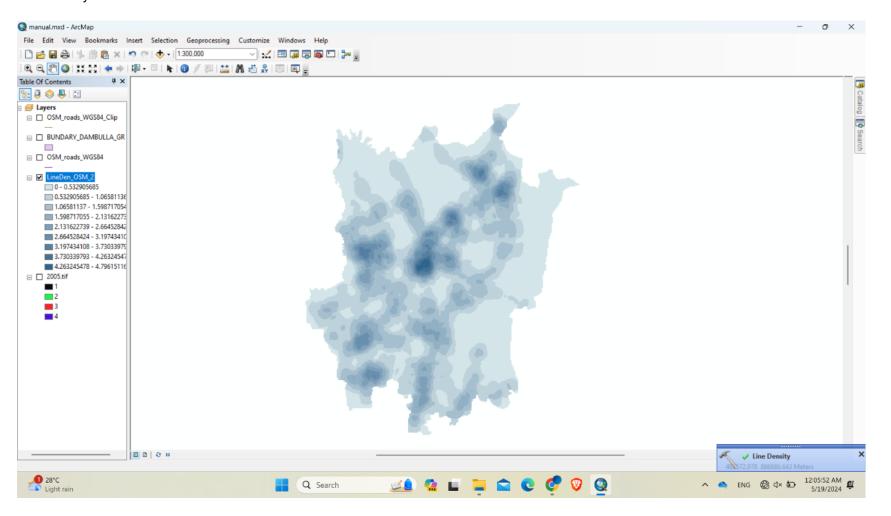


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Then click "**OK**" to come back to the line density tool as follows. Again click on "**OK**" to run the tool.

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Once the Line Density tool has finished running, the new road density raster will be added to your map. Review the output to ensure it accurately represents road density.



8. Check the coordinate system, pixel size, and rows & columns

- I. Right-click on the layer in the Table of Contents.
- II. Select "Properties".
- III. In the Layer Properties dialog box, go to the "Source" tab.

The coordinate system information will be displayed in this tab. Ensure that it matches the desired coordinate system for your project.

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9. Resample a Raster File.

If you notice that the raster file does not have the correct pixel size or number of rows and columns, you can resample it. (The first result obtained here is the same as the 2005 raster file values, so there is no need for a resample.)

Open the Resample Tool

Go to "ArcToolbox" and navigate to Data Management Tools > Raster > Raster Processing > Resample

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Set Resample Tool Parameters

In the Resample dialog box, set the following parameters:

- I. Input Raster: Select the raster file that needs resampling.
- II. Output Raster Dataset: Specify the location and name for the resampled raster file.
- III. Output Cell Size: Enter the desired cell size for the resampled raster. This should match the pixel size you need.

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Change Environment Settings

Go to the "Environments".

In the Environment Settings dialog box, set the following:

- I. If the output raster needs to match an existing raster's pixel size and alignment exactly, use the environment setting. Go to Environments.
- II. Then set up the workspace as the default workspace.
- III. Under "Raster Analysis," set the "Cell Size" to match your existing raster and set the "Mask" to match your existing raster.
- IV. Under "Processing Extent," set the "Extent" to your existing raster layer.

- Cell Size: Set this to match the cell size of your resampled raster.
- Mask: Optionally, you can set a mask to limit processing to a specific area.

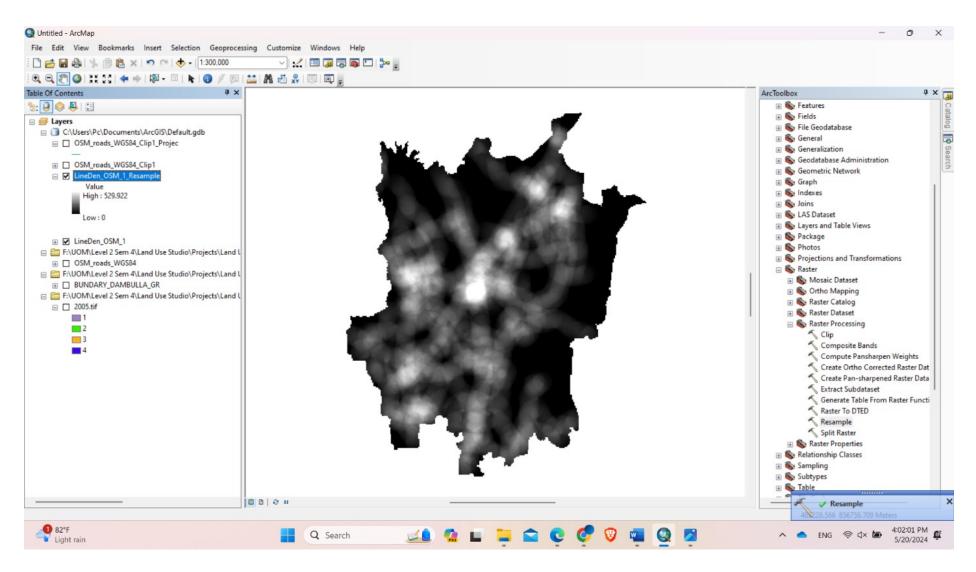
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Run the Resample Tool

Click "OK" to run the Resample tool. The tool will process the data and create a new raster with the specified cell size.

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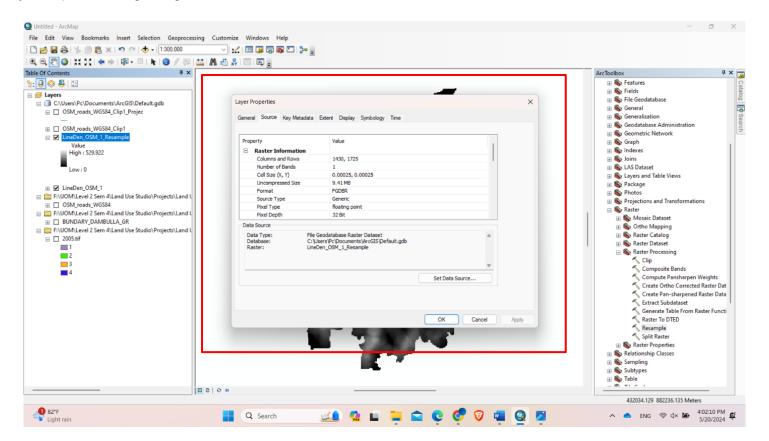
After that, you can see the resampled layer as follows.



Again, check pixel size and rows columns.

• Right-click on the layer in the Table of Contents.

- Select "Properties".
- In the Layer Properties dialog box, go to the "Raster Information" tab.



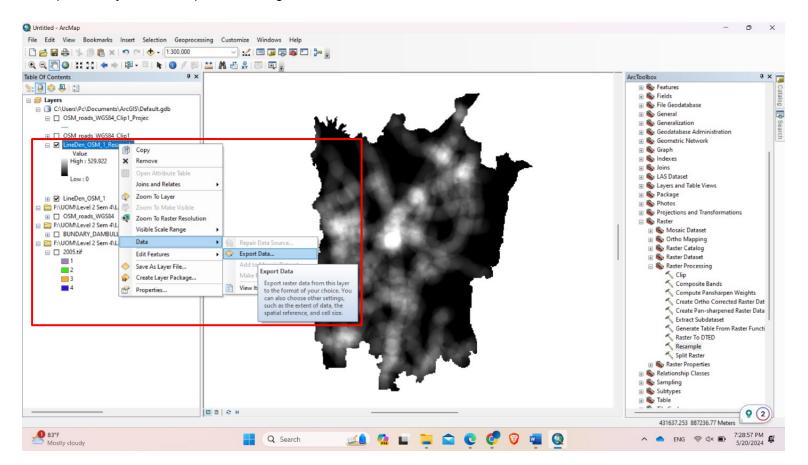
• If it is not the same this time, resample it again and then export this layer.

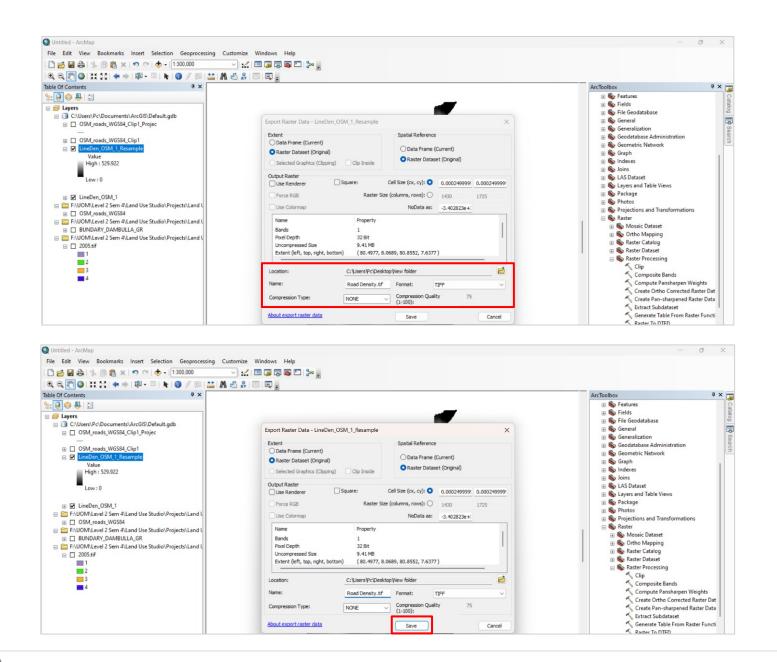
10. Export Layer

- I. Right-click on the layer you want to export in the Table of Contents.
- II. Select "Data" and then "Export Data".
- III. In the Export Data dialog box, specify the location and file format for the exported layer.

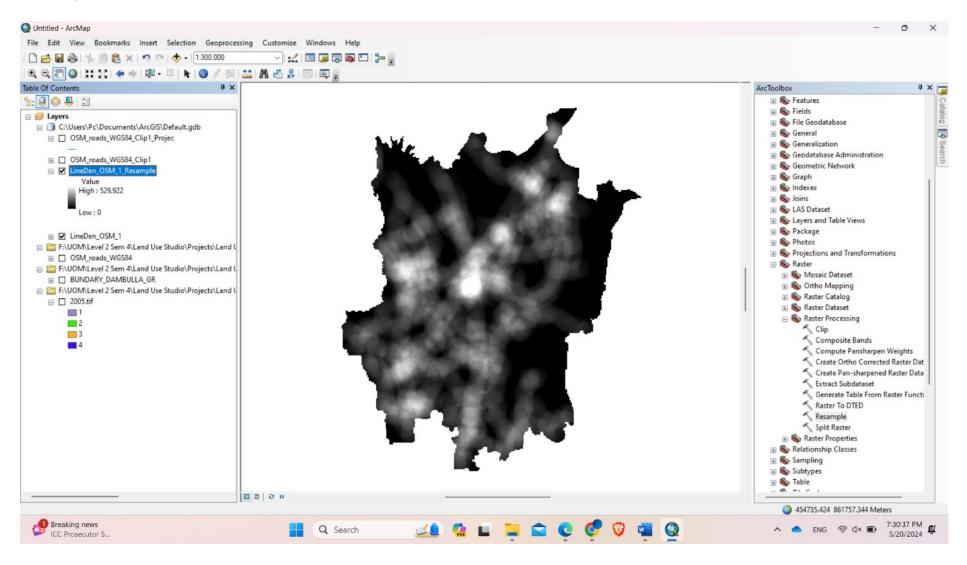
Optionally, you can select the extent and coordinate system for the exported data.

Click "OK" to export the layer with the specified settings.





Now that we have created and verified the road density raster layer, we can use it as a key input for the MOLUSCE (Module for Land Use Change Evaluation) land use prediction model.



3. Euclidean distances between roads

Considering the Euclidean distance between roads as a factor in land use prediction is crucial for several reasons. Firstly, accessibility and connectivity are significantly impacted by the proximity to roads. Areas closer to roads generally have better access to transportation networks, making them more attractive for residential, commercial, and industrial developments. This improved accessibility often leads to the development of infrastructure and services, further enhancing the appeal of these areas for various land uses.

Economic development is another key reason for considering Euclidean distance between roads. The distance to roads directly affects transportation costs for businesses, with shorter distances typically resulting in lower costs. This can influence business location decisions and promote economic activities in well-connected areas.

In terms of urban planning and expansion, the Euclidean distance to roads is an essential factor in land use allocation. Urban planners use road proximity to ensure that residential areas are close to necessary amenities and that commercial zones have adequate transportation access. This helps in predicting urban sprawl patterns, as areas near existing roads are more likely to be developed, shaping the overall growth and development of urban regions.

To prepare the Euclidean distance for the road layer, follow the same steps as preparing the road density factor, up to clipping the road layer and ensuring the coordinate system is correct.

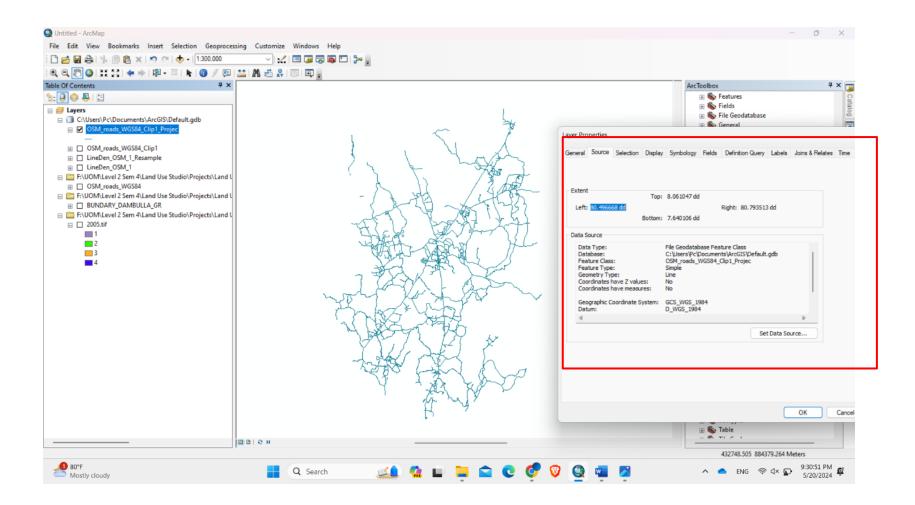
1. Prepare the Road Layer

• Download and Add Road Layer: Download the road layer for Sri Lanka from OpenStreetMap and add it to ArcMap.

OpenStreetMap: <u>https://www.openstreetmap.org/#map=7/7.879/80.767</u>

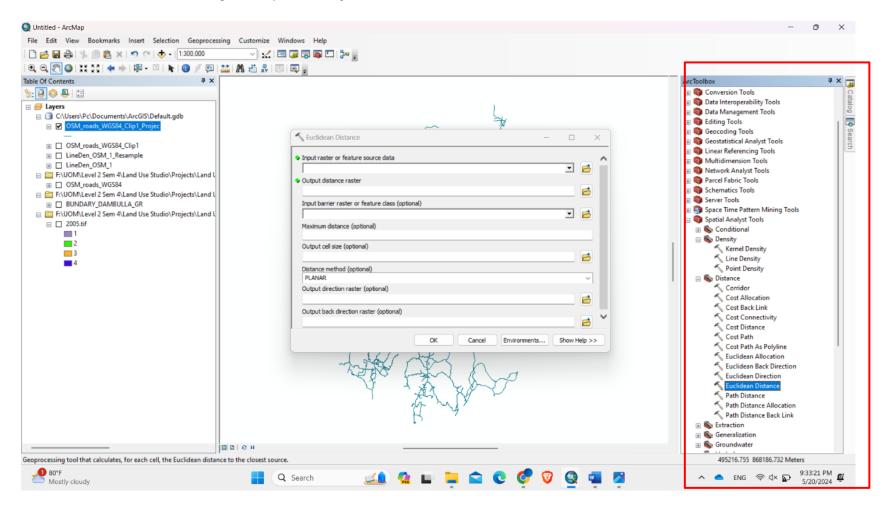
How to download GIS shapefile data from OSM: <u>https://www.youtube.com/watch?v=iA2AF4f1_g4</u>

- Clip Road Layer: Use the Clip tool to restrict the road layer to the relevant area using a boundary shapefile.
- Check Coordinate System: Verify the coordinate system of the clipped road layer with the previously prepared 2005 land use raster layer and ensure it matches your project's coordinate system. Use the "Project" tool if necessary to align the coordinate systems.



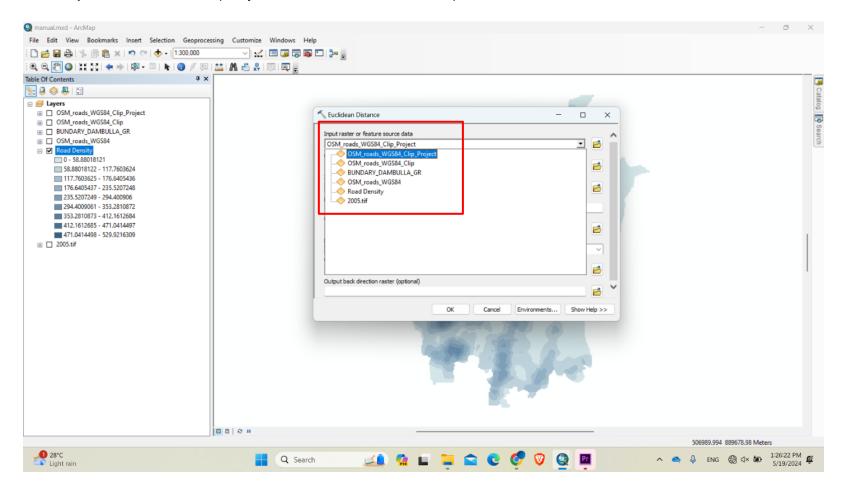
2. Run the Euclidean Distance Tool

Go to "ArcToolbox" and navigate to Spatial Analyst Tools > Distance > Euclidean Distance.



In the Euclidean Distance dialog box, set the following parameters:

- I. Input Raster or Feature Source Data: Select your clipped road layer.
- II. Output Distance Raster: Specify the location and name for the output distance raster file.



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In the **Environment Settings** dialog box, make the following adjustments.

I. Processing Extent:

Set the "Extent" to match your 2005 land use raster. You can choose the raster layer from the dropdown list to ensure the extent matches exactly.

II. Raster Analysis:

Cell Size: Set the cell size to match the cell size of your 2005 land use raster. You can select the raster layer to automatically match the cell size.

III. Mask:

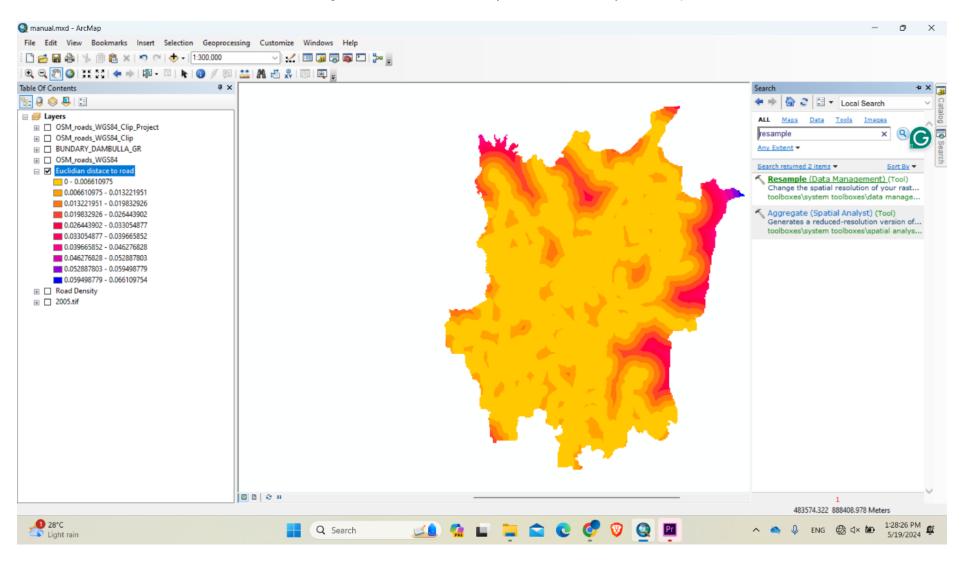
Optionally, you can set a mask to limit the processing to the area covered by your 2005 land use raster.

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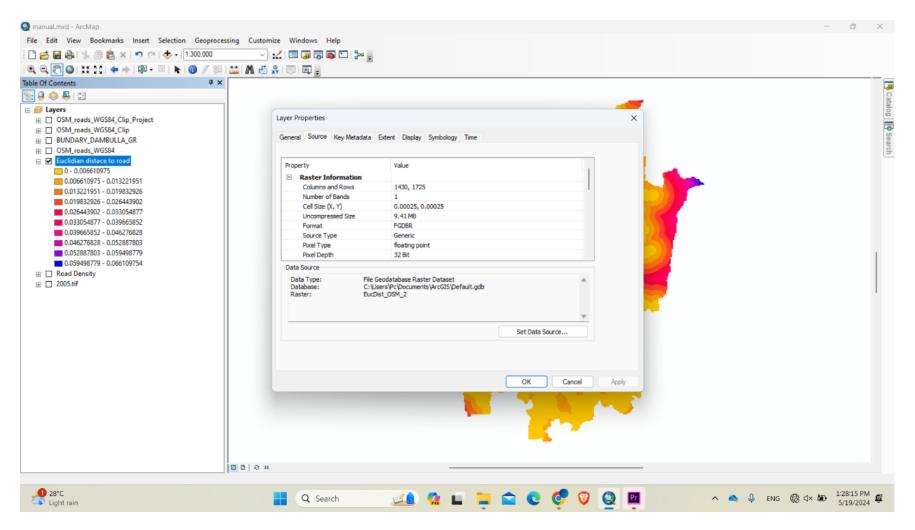
Click "**OK**" to run the tool. The tool will process the data and create a new Euclidean distance raster layer.

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Once the Euclidean Distance tool has finished running, the new distance raster layer will be added to your workspace.



- After that, Right-click the new Euclidean distance raster layer in the Table of Contents.
- Select "Properties" and go to the "Source" tab to confirm that the coordinate system, extent, cell size, and rows/columns match your 2005 land use raster.



If these rows and columns are not equal, resample again and again like the previous road density and create your layer.

4. Euclidean distances to the nearest town centers

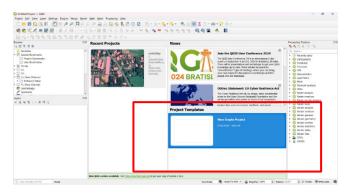
Incorporating the "Euclidean distances to the nearest town centers" as a factor for land use prediction holds several merits. Firstly, proximity to town centers often correlates with patterns of human activity and development. Towns typically serve as hubs of commerce, services, and residential areas, exerting a significant influence on surrounding land use.

The Euclidean distance metric provides a straightforward and intuitive measure of spatial relationship. It offers a clear representation of how far a given location is from the nearest town center, facilitating easy interpretation and integration into predictive models. Considering the distance to town centers acknowledges the influence of infrastructure and amenities associated with urban areas.

Incorporating the Euclidean distances to the nearest town centers as a factor in MOLUSCE enhances its ability to predict land use changes by capturing the spatial dynamics of urbanization, accessibility to amenities, and the influence of infrastructure. By leveraging this metric, MOLUSCE can provide valuable insights into the evolving patterns of land use in diverse landscapes.

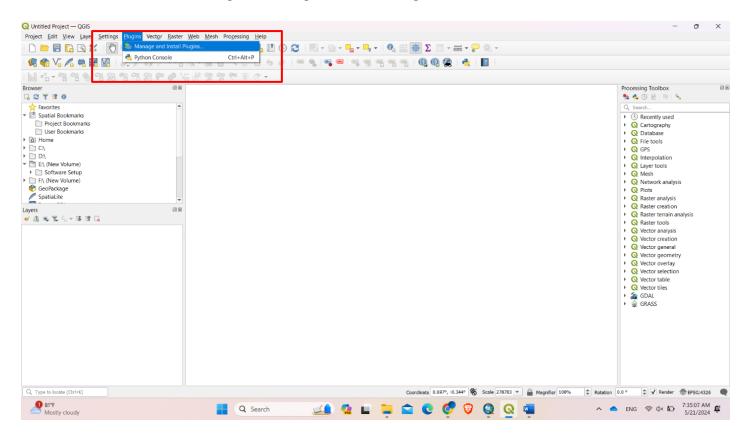
1. Open QGIS.

Open QGIS and create a new project.

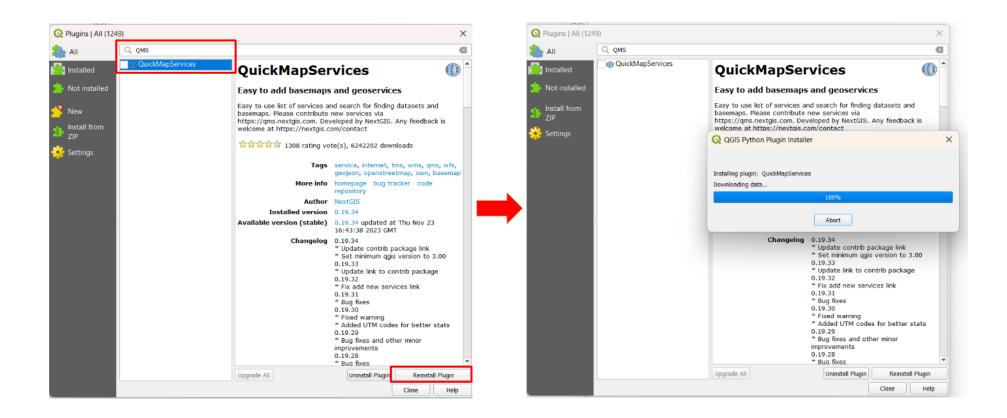


2. Adding a basemap.

Go to the menu and select Plugins > Manage and Install Plugins.



- In the Plugin Manager, search for "QuickMapServices" and install it.
- If it is already installed, it will show as "Reinstall". If not installed, it will show "Install".

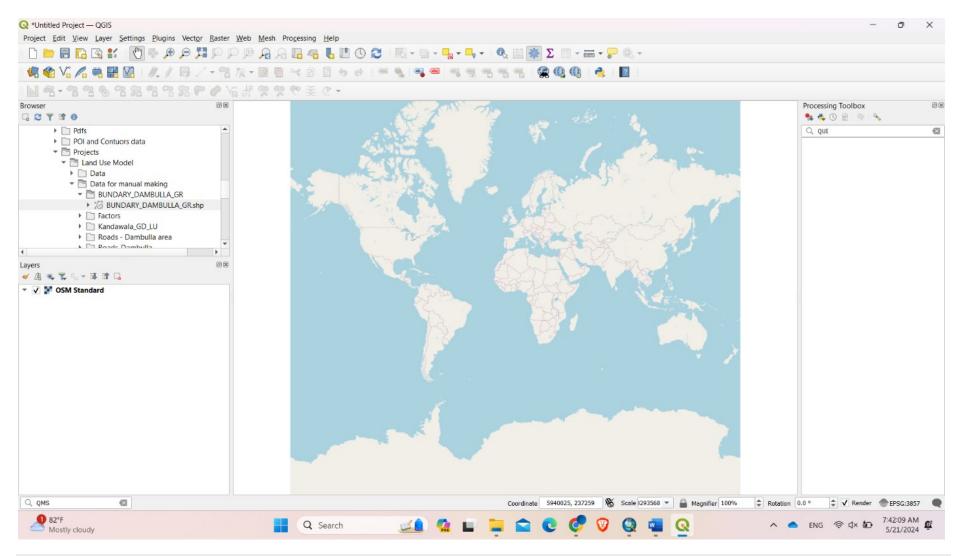


- Once installed, go to Web > QuickMapServices > Settings.
- In the "QuickMapServices Settings" dialog, click on "More Services" and then "Get contributed pack" (That's for the latest update on maps)
- Close the dialog and go to **Web > QuickMapServices** to choose a base map.
- Select a base map provider from the list (e.g. OpenStreetMap, Google Maps) and click on it to add it to your project.

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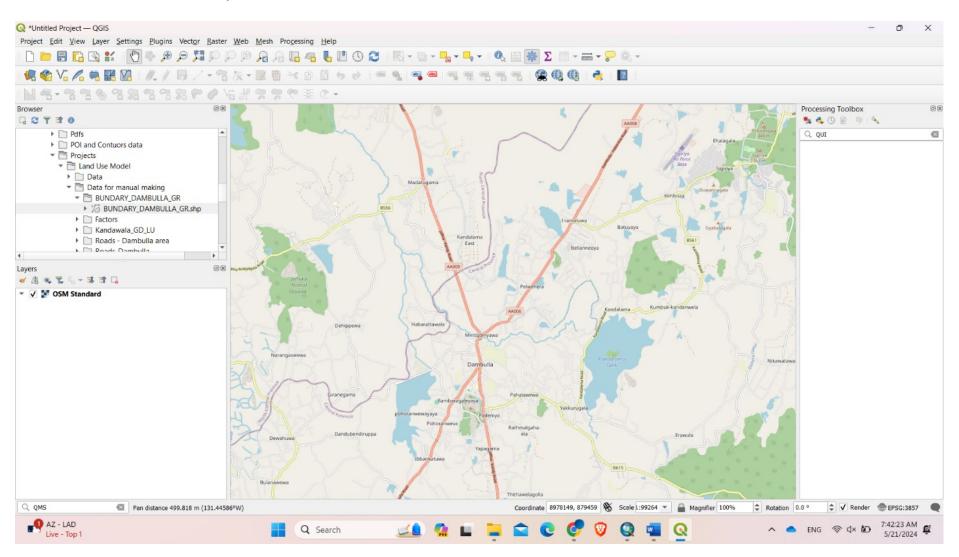
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The base map will be added as a new layer in the Layers Panel.



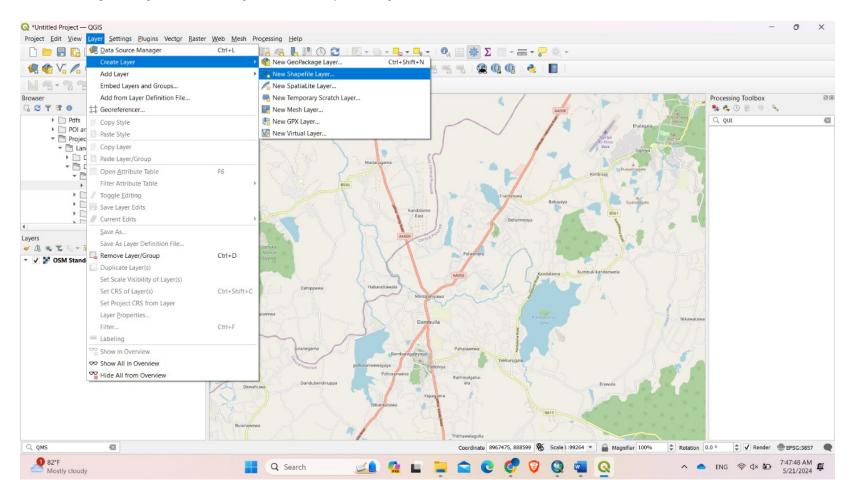
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Use the mouse cursor and zoom to your area.

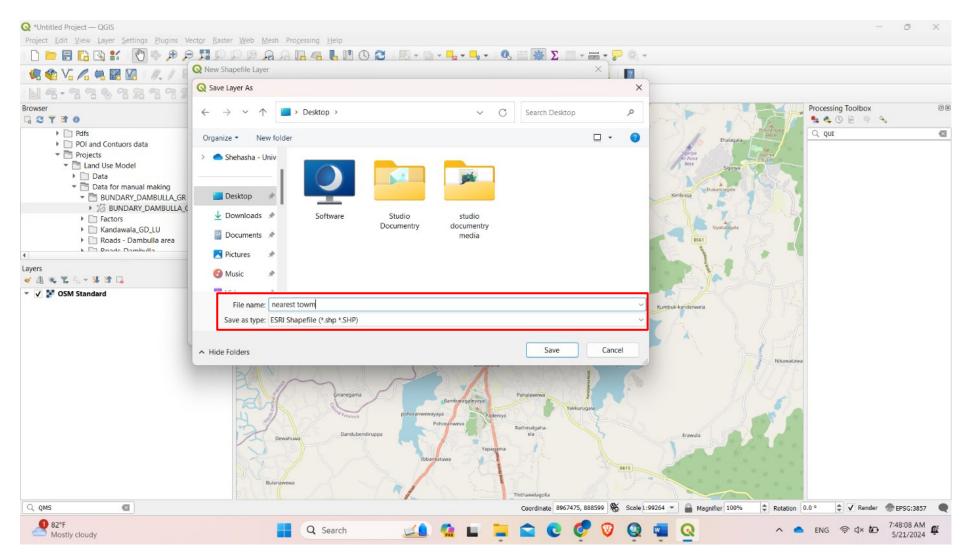


3. Creating a Shapefile.

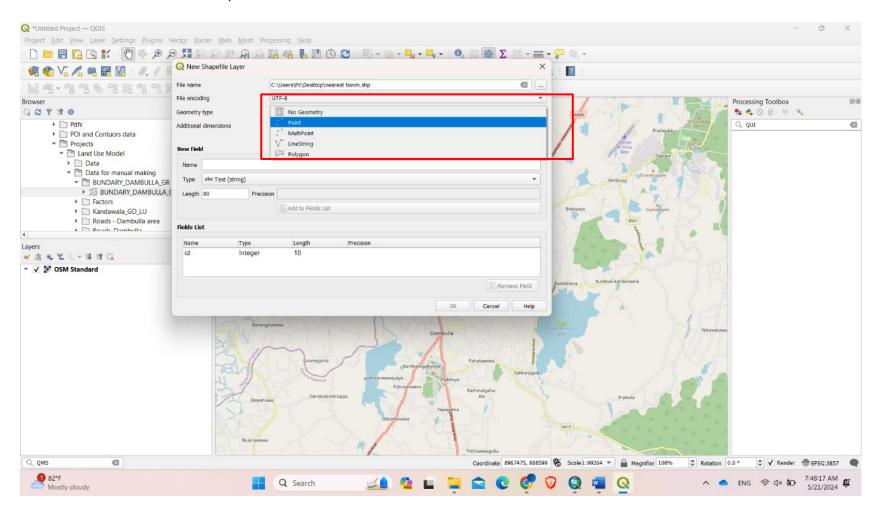
In the menu, go to Layer > Create Layer > New Shapefile Layer.



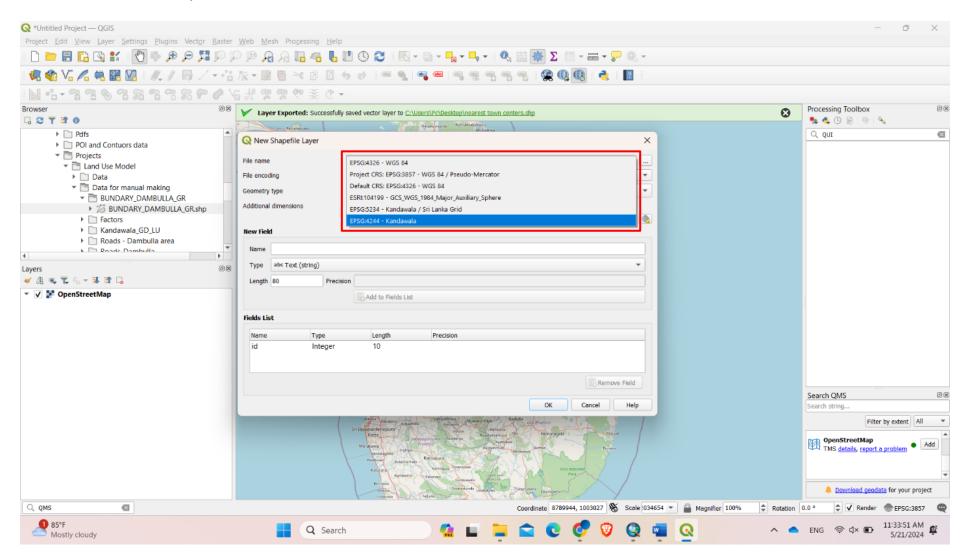
Choose a directory to save the shapefile and give it a name.



In the "New Vector Layer" dialog box, specify the type of feature (point, line, or polygon), coordinate reference system (CRS), and attribute fields. Here I want to mark towns and therefore select points.



Then Select the coordinate system.

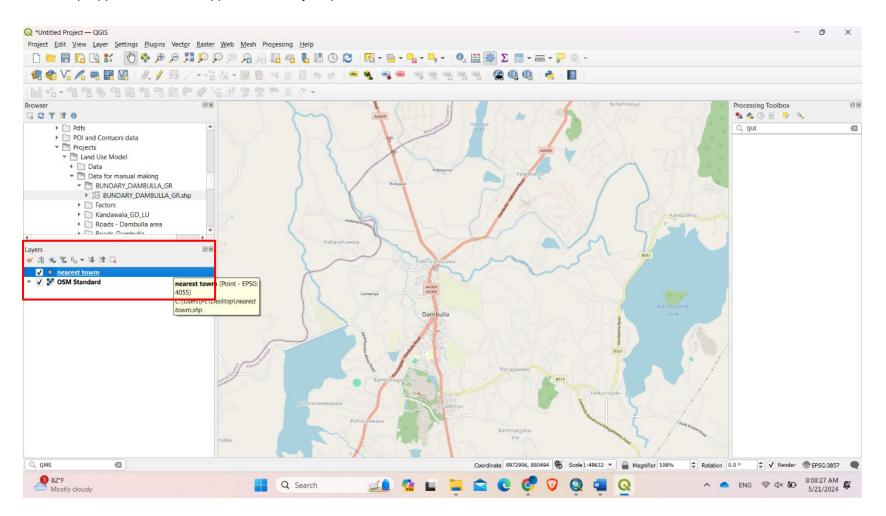


At this point, a column was added as a name to the attribute table.

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Click **"OK**" to create the shapefile.

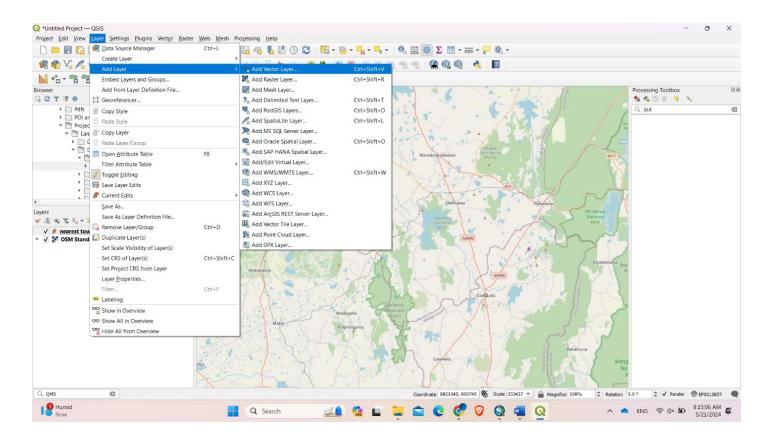
Now the (.shp) file we created appears in the layers panel on the left.



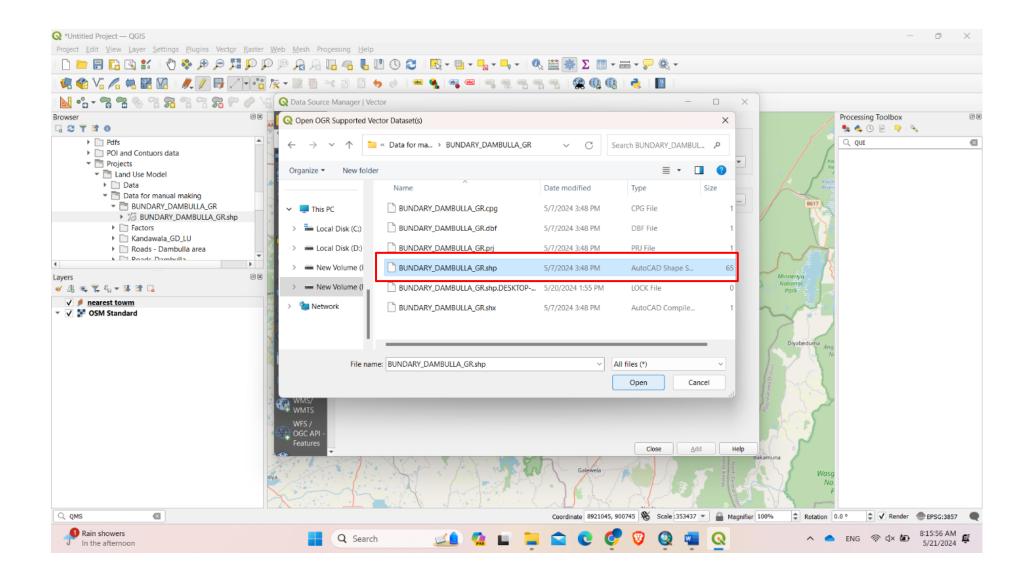
To facilitate the identification of relevant areas, we have included the boundary shapefile for the Greater Dambulla area. This addition allows for easier and more accurate delineation of the specified region.

4. Add the boundary Shapefile layer.

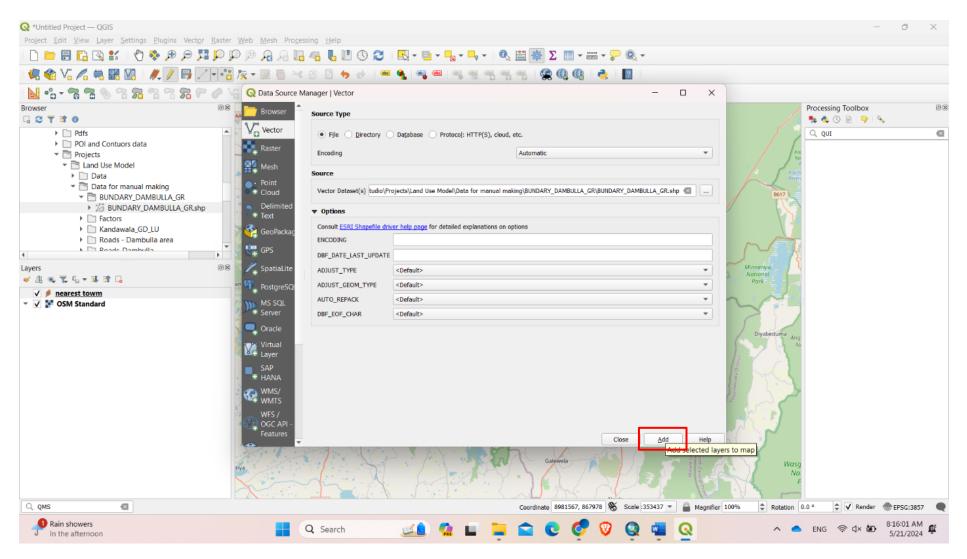
- Go to Layer > Add Layer > Add Vector Layer.
- Alternatively, you can click the Add Vector Layer button in the Data Source Manager toolbar.
- Open the Data Source Manager
- In the Data Source Manager dialog, click the ... button next to the Vector Dataset(s) field.



- Navigate to the location where your boundary shapefile is stored.
- Select the Shapefile
- Select the shapefile (.shp extension) you want to add.



Back in the Data Source Manager dialog, click "Add".



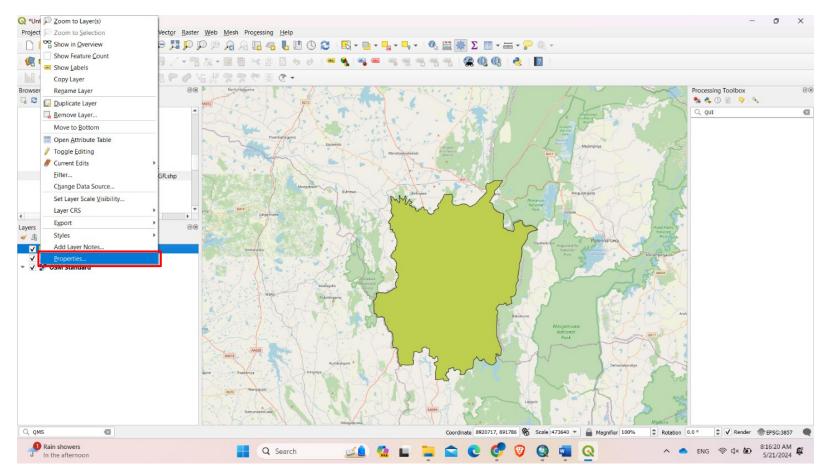
Your boundary shapefile will now be added to the Layers Panel.

Verify the Layer

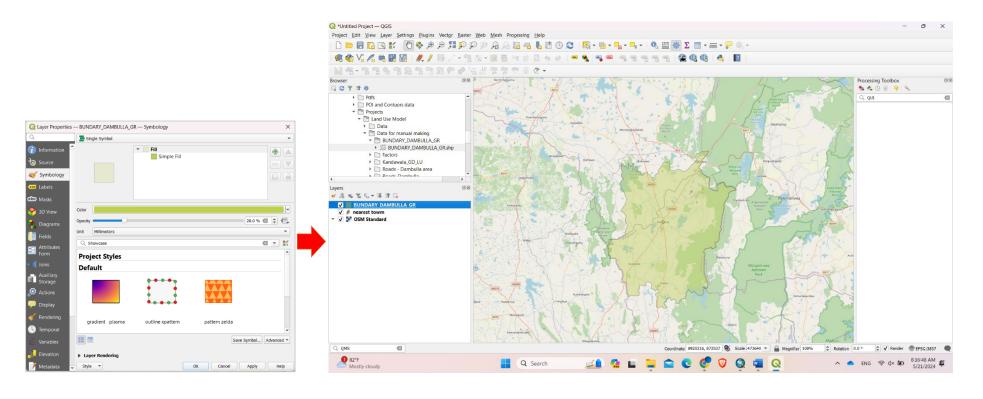
- Ensure the boundary layer appears in the Layers Panel.
- You can right-click on the layer and select Zoom to Layer to view the full extent of your boundary.

Adjust Layer Styling (Optional)

• To change the appearance of the boundary, right-click on the layer and select Properties.

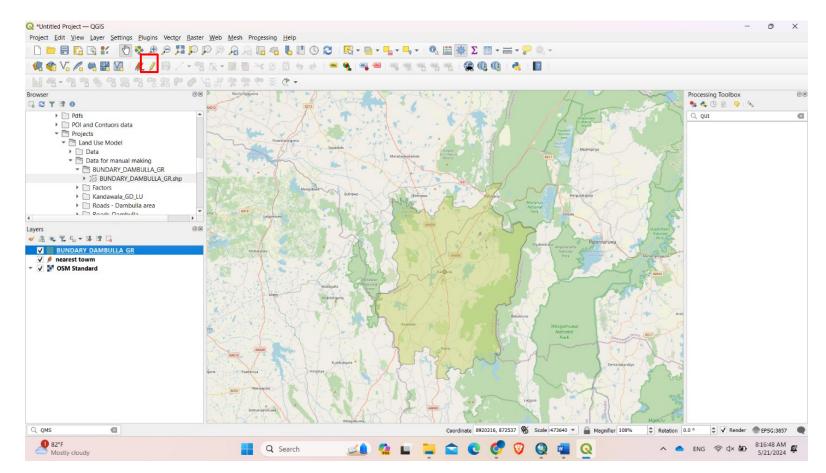


- In the Layer Properties dialog, go to the Symbology tab and adjust the style settings as needed.
- Here I have adjusted the opacity.

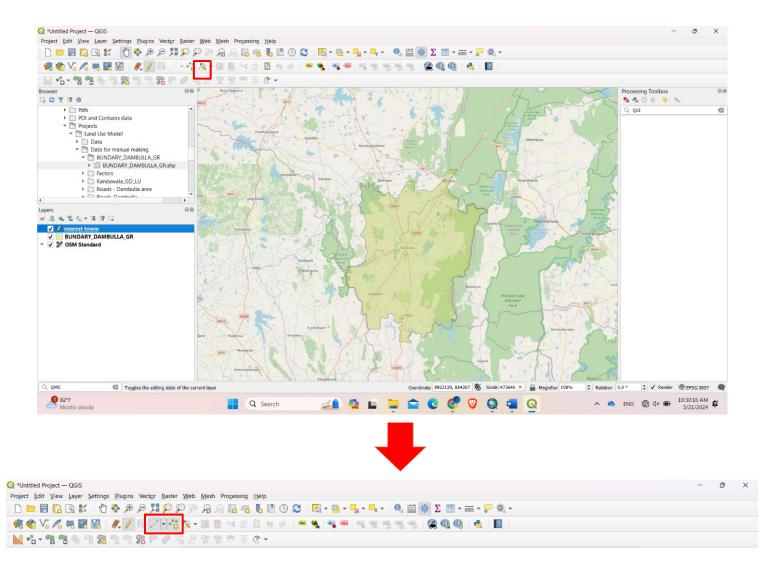


5. Digitizing Features.

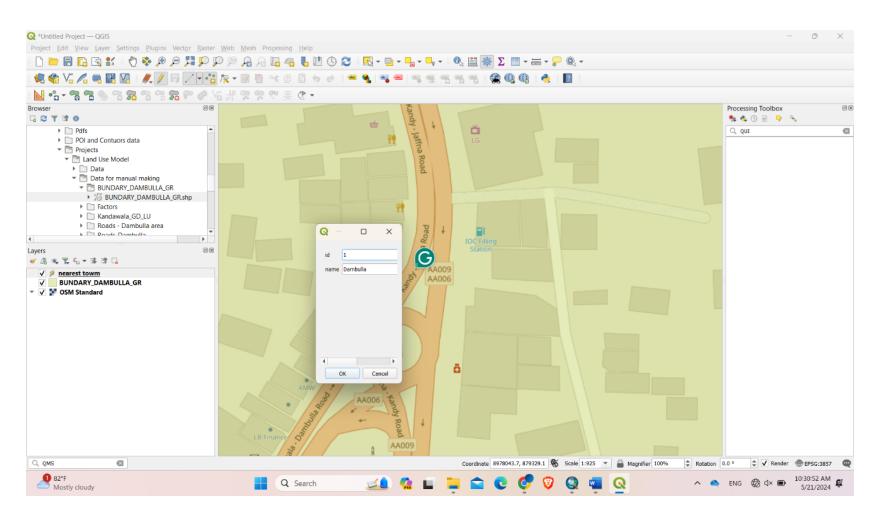
- Select the layer you want to digitize in the Layers Panel.
- Make sure the editing mode is enabled by clicking the **"Toggle Editing"** button in the Digitizing toolbar.



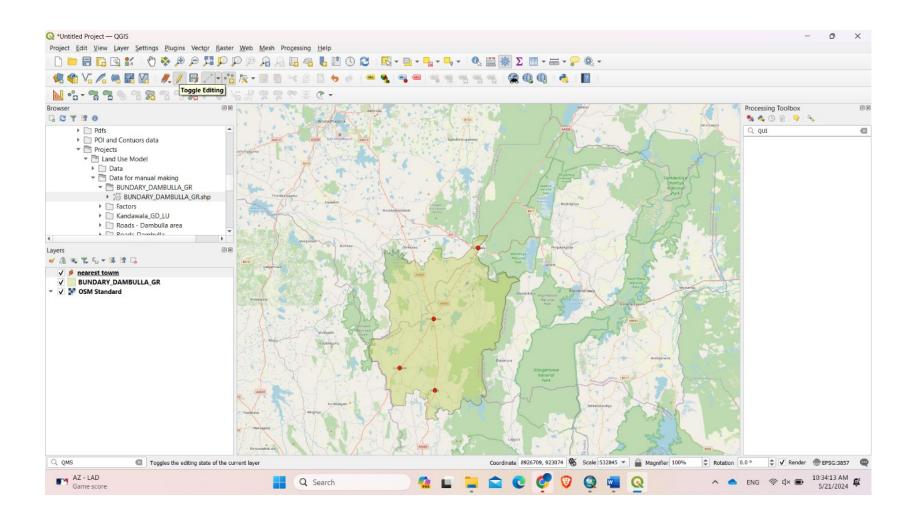
Choose the appropriate digitizing tool from the Digitizing toolbar.



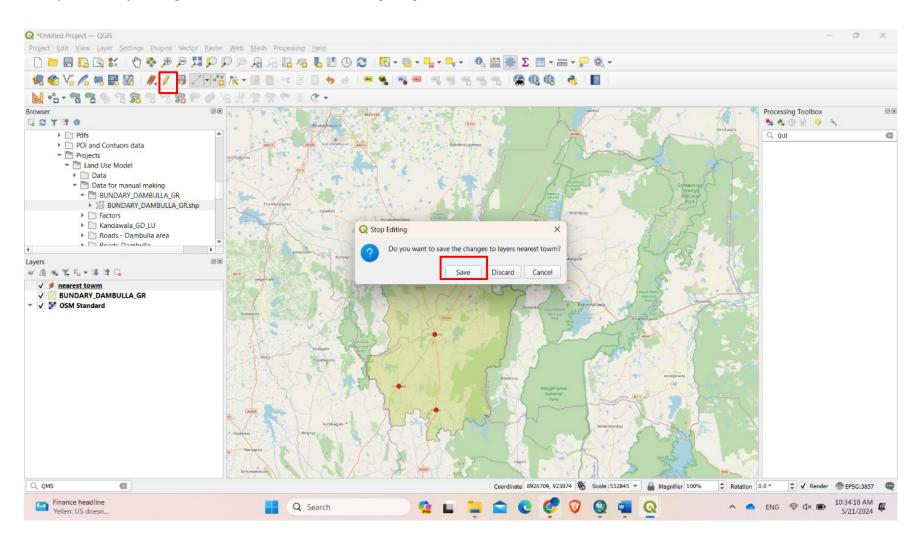
- Start digitizing by clicking on the map canvas to create points.
- After clicking on a point, fill in attribute values for each feature using the attribute table.



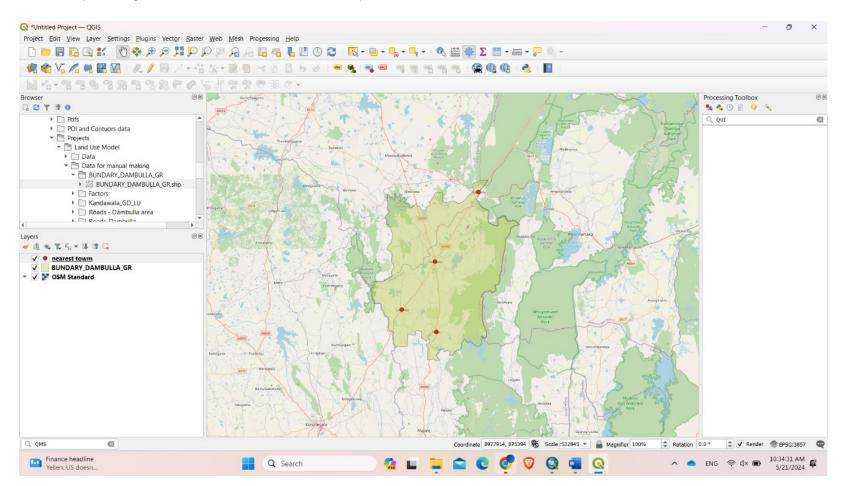
Here are the added points according to the above way.



Save your edits by clicking the "Save Edits" button in the Digitizing toolbar. Then click on "Save".



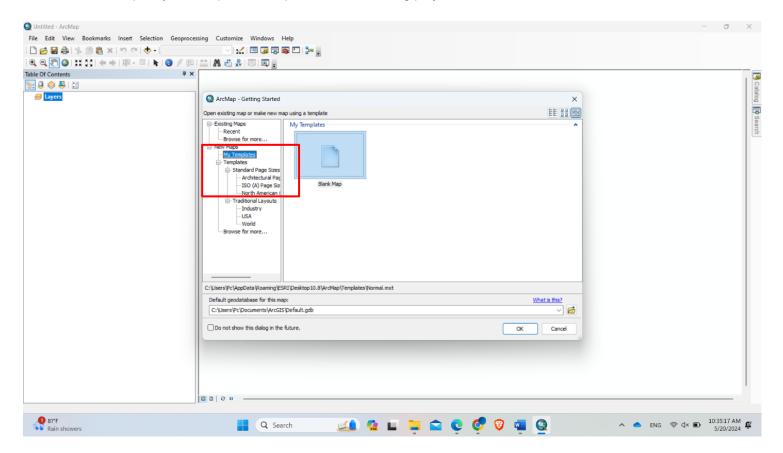
You've created a shapefile, digitized features, and added a base map in QGIS.



We will utilize ArcMap software for this task because it simplifies the process of calculating Euclidean distances to the nearest town centers. However, for other components of our analysis, such as point digitization, we will use QGIS. Using QGIS can't make an Euclidean distance map like the land use layer, so we will use ArcMap Software.

6. Open ArcMap

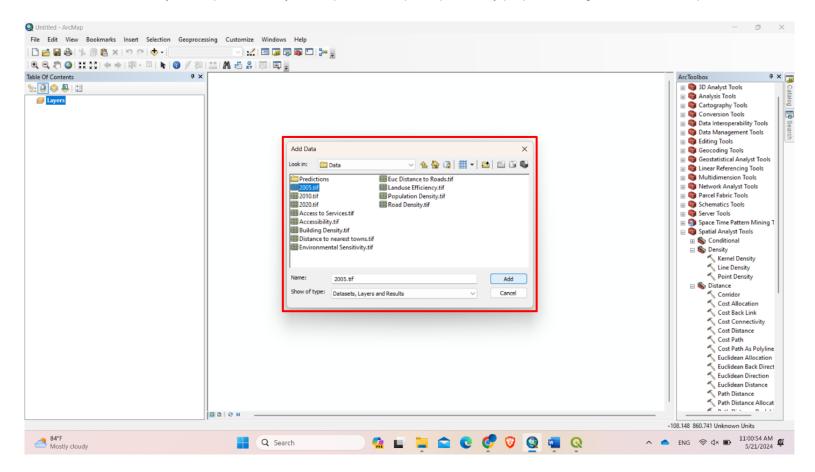
Launch ArcMap on your computer and open a new or existing project.

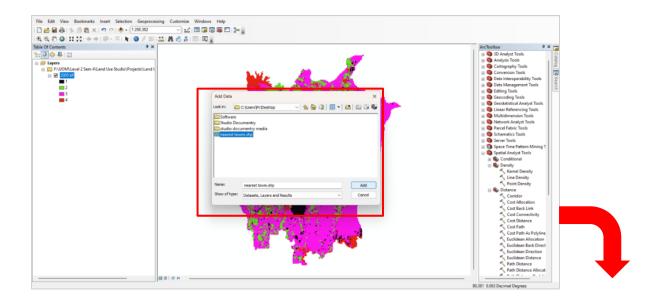


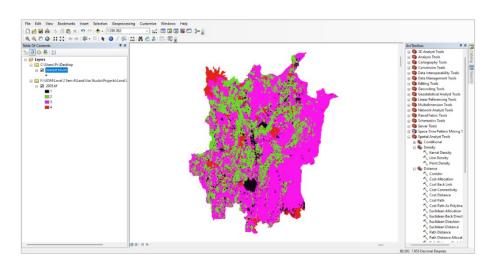
7. Add Shapefiles to the Map

• Go to File > Add Data > Add Data

- Navigate to and select your shapefiles for the town centers and land use layers. (The 2005 land use raster layer is needed because the raster file that is being created now wants to follow same the pixel size of the land use layer)
- Click "Add" to load them into your map. In this way, we import the shapefile previously prepared using QGIS into ArcMap.







8. Ensure Consistent Coordinate Systems

- First, make sure that all your layers (Town centers layer and Land use layer) have the same coordinate system.
- Right-click each layer in the Table of Contents, select "**Properties**," then go to the "**Source**" tab to check the coordinate system.

Layer Properties General Source Key Metadata Extr	ent Display Symbology Fields Joins & Relates Time	×	Layer Properties × General Source Selection Display Symbology Reds Definition Query Labels Joins & Relates Time HTML Popup
Folder: F:\UOM\	em Raster	-	Extent Top: 8.039716 dd Left: 10.0000965 Right: 80.755768 dd Bottom: 0.000009 Data Source Data Type: Shapefile Feature Class Shapefile: C-Ulaers/PC/Deaktop/nearest town centers.shp Geometry Type: No Coordinates have z values: No Geographic Coordinate System: GCS_Kindwalah Datam: Datam: Greenwich
Raster: 2005.6f	v Set Data Source	Acoly	Angular Unit: Degree

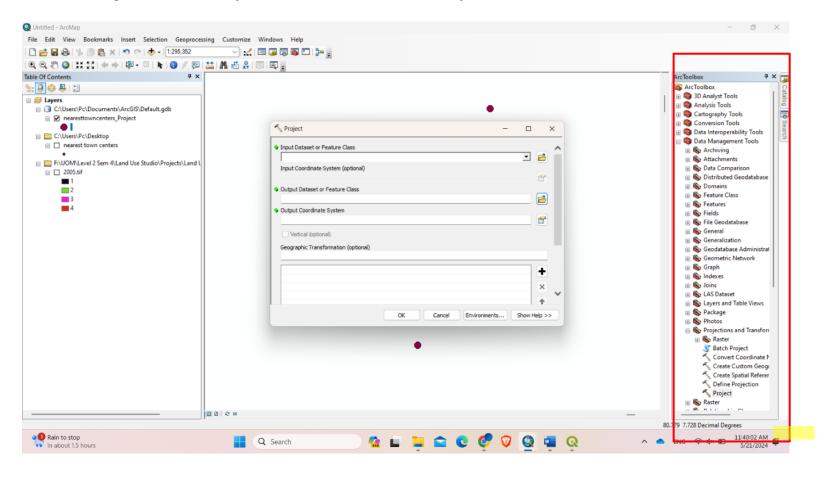
After that, checked and noted the pixel size and rows columns of the 2005 Land use raster file.

roperty Raster Information	Value	
Columns and Rows	1430, 1725	
Number of Bands	1	
Coll Fire (V. V)	0.00035.0.00035	
Uncompressed Size	2.35 MB	
Format	TIPP	
Source Type	Thematic	
Pixel Type	signed integer	
Pixel Depth Data Source	8 Bit	
Folder: F:	e System Raster NOML evel 2 Sem 4k and Use Studio Projects k and Use Model Pata	
	Set Data Source	

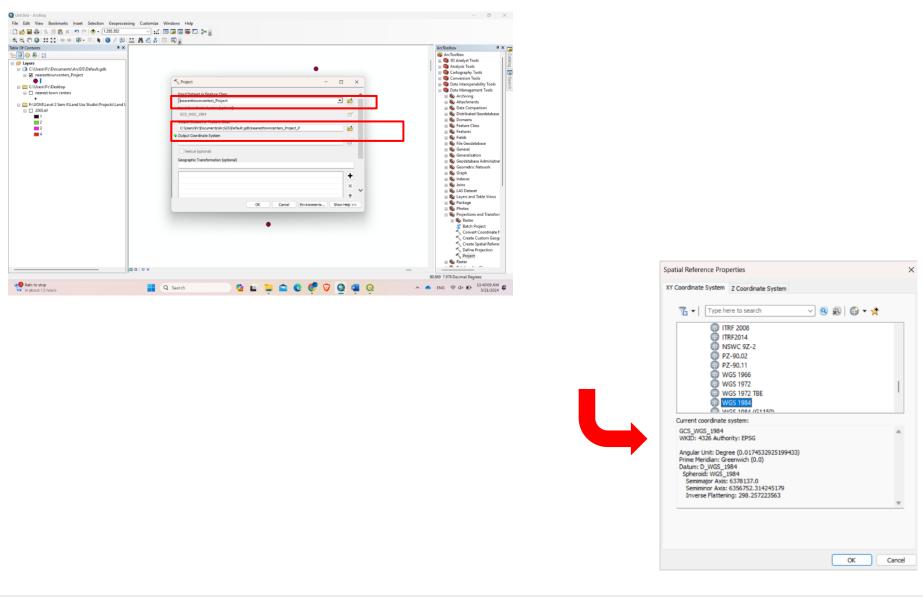
Upon examination, I observed discrepancies in the coordinate system of the town center file.

9. Project (.shp) file to the same coordinate system

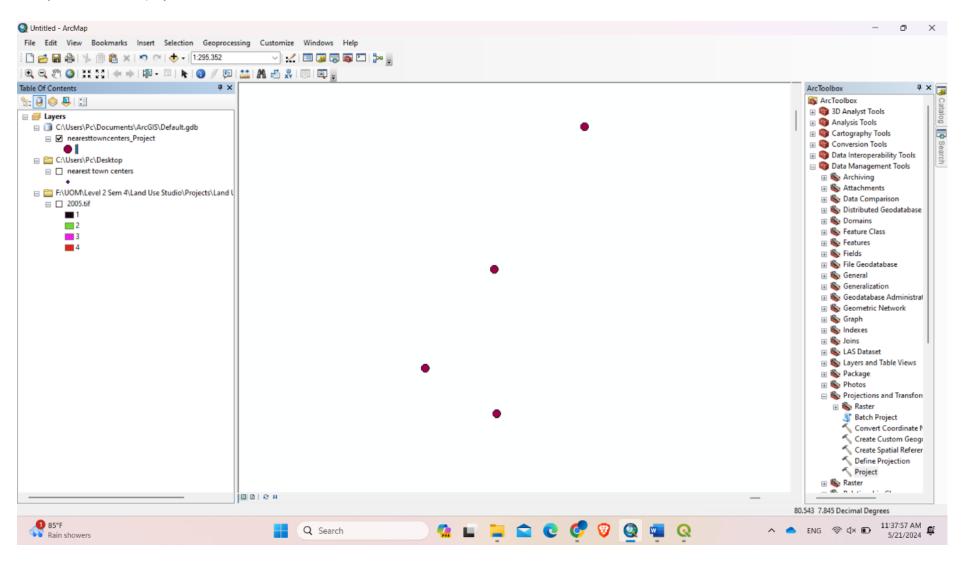
- Consequently, I utilized the "Project" tool to rectify the coordinate system of the Town center's file to match the desired one.
- If any layers have different coordinate systems, you need to project them to the same coordinate system. You can use the "Project" tool found under Data Management Tools > Projections and Transformations > Project on ArcToolBox.



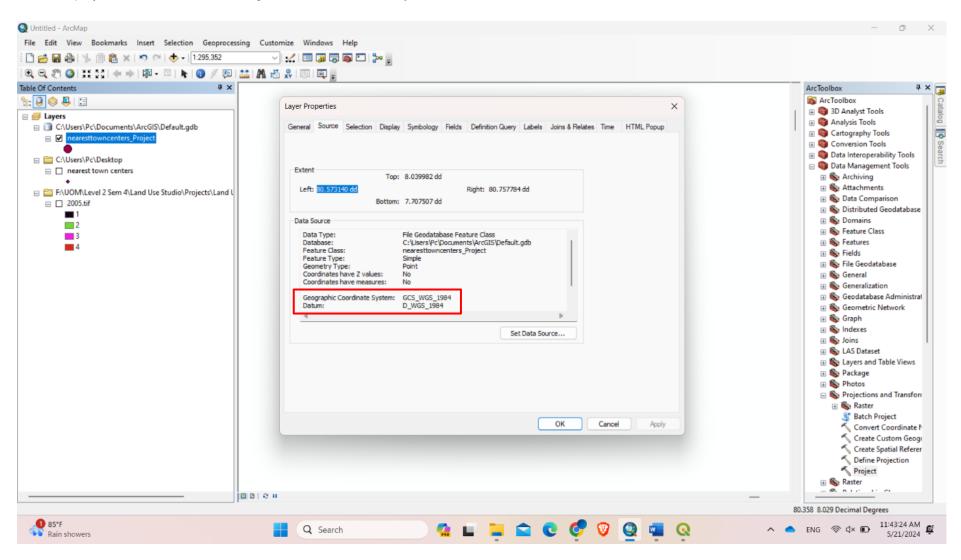
Select the projected town centers layer to the Input Dataset or feature class and select 2005 Land use raster layers' coordinate system to coordinate system.



Now you can see the projected town centers file.



Once the project tool has finished running, check the coordinate system of the raster file.



10. Open the Euclidean Distance Tool

Go to ArcToolbox > Spatial Analyst Tools > Distance > Euclidean Distance.

🔕 Untitled - ArcMap		- 0 ×
File Edit View Bookmarks Insert Selection Geoprocessing Cu	terin Weder He	<u> </u>
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Table Of Contents # ×		ArcToolbox 4 ×
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B S Layers		😑 😂 Spatial Analyst Tools
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nearesttowncenters_Project		G Space Time Pattern Mining 1 G Spatial Analyst Tools G Spatial Analyst
	Seuclidean Distance – 🗆 🗙	Corridor
		🔨 Cost Allocation
□ nearest town centers	Input raster or feature source data	🔨 Cost Back Link
F:\UOM\Level 2 Sem 4\Land Use Studio\Projects\Land L		S Cost Connectivity
□ 2005.tif	Output distance raster	Cost Distance
■1		Cost Path
2	Input barrier raster or feature class (optional)	Securities Folyme
3		🔨 Euclidean Back Direct
4	Maximum distance (optional)	🔨 Euclidean Direction
	Output cell size (optional)	🔨 Euclidean Distance
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	Distance method (optional)	Path Distance Allocat Path Distance Back Li
	PLANAR	Extraction
	Output direction raster (optional)	🕀 🗞 Generalization
		🗄 🚳 Groundwater
	Output back direction raster (optional)	🕀 🗞 Hydrology
		Solution
		🗉 🗞 Local 🗄 🗞 Map Algebra
	OK Cancel Environments Show Help >>	Map Algebra
		🕀 🗞 Multivariate
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		Rester Creation
		Segmentation and Classi
		Solar Radiation
		🕀 🍆 Surface
		🗉 🚳 Zonal
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Geoprocessing tool that calculates, for each cell, the Euclidean distance to the	closest source.	80.92 7.877 Decimal Degrees
40 85°F		11:44:55 AM
Rain showers	📕 Q Search 🤷 🖬 📮 🕿 😨 🦉 🧕 🖷 Q 🔷 🔹	► ENG Q× ■ 11:44:55 AM 5/21/2024

Configure the Euclidean Distance Tool

- I. Input raster or feature source data: Select the town center point layer.
- II. **Output distance raster:** Specify the location and name of the output raster file.
- III. Maximum distance (Optional): Set a maximum distance limit if needed.
- IV. **Output cell size:** Ensure it matches the cell size set in the Environment Settings.

Set the Environment Settings

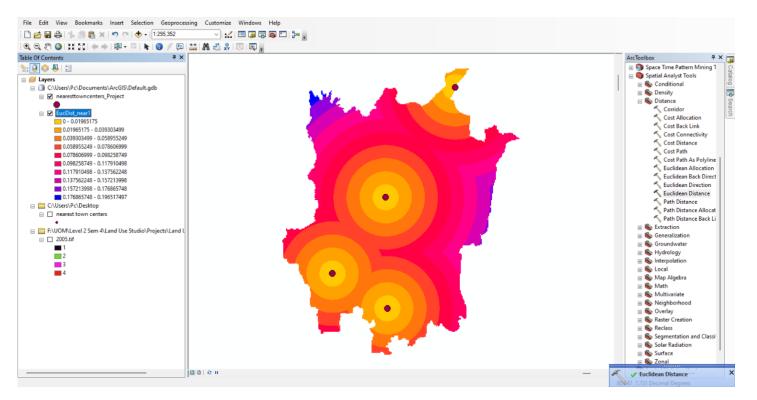
- Go to Environments.
- In the Environment Settings dialog box, set the following:
 - > Workspace: Set the current and scratch workspace.
 - > **Processing Extent:** Set to the same as your land use layer.
 - Raster Analysis Settings:

Cell Size: Set the cell size (pixel size) to match the resolution of your land use layer.

Mask: Set the mask to your land use layer to ensure the output raster matches the area of interest.

Renvironment Settings	The Environment Settings X	Suclidean Distance – 🗆 🗙
× Workspace		Input raster or feature source data
Output Coordinates Processing Extent Extent		Output distance raster C: [Jisers \Pc]Pocuments \ArcGIS\Default.gdb EucDist_near1
Same as layer 2005. tif Carlor	Same as layer 2005.thf V 2002499999999991	Input barrier raster or feature class (optional)
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Same as layer nearest town centers Project Same as layer nearest town centers Same as layer 2005 tri Same as layer 2005 tri Same As layer 2005 tri	ZODS.tif Z Costif	F: UOMILevel 25 em 4Land Use Studio Projects Land Use Model Data 2005.0f
XY Resolution and Tolerance	× Geostatistical Analysis × Parallel Processing	PLANAR Output direction raster (optional)
× M Values ✓	× Remote Processing Server	Output back direction raster (optional)
Z Values OK Cancel Show Help >>	Vertical Cancel Show Help >>	OK Cancel Environments Show Help >>

By following these steps, you will create an Euclidean distance raster map that shows the distances from each cell to the nearest town center, with the correct pixel size and dimensions matching the land use layer.



operty	Value		Property	Value	
Raster Information			Right	80.85525	
Columns and Rows	1430, 1725		Bottom	7.63765895522	
Number of Bands	1		Spatial Reference		
Cell Size (X, Y)	0.00025, 0.00025		XY Coordinate System	GCS_WGS_1984	
Uncompressed Size	9.41 MB		Linear Unit		1
Format	FGDBR.		Angular Unit	Degree (0.0174532925199433)	
Source Type	Generic		Datum	D_WGS_1984	
Pixel Type	floating point		Vertical Coordinate Syst	e	
Pixel Depth	32 Bit		Statistics		
ata Source			Data Source		
Database: C:\U	ieodatabase Raster Dataset sers\Pc\Documents\ArcGIS\Default.gdb ist_near1		Database: C:\Us	eodatabase Raster Dataset ers\Pc\Documents\ArcGIS\Default.gdb st_near1	A
		V			•
	Si	et Data Source			Set Data Source

5. Population Density

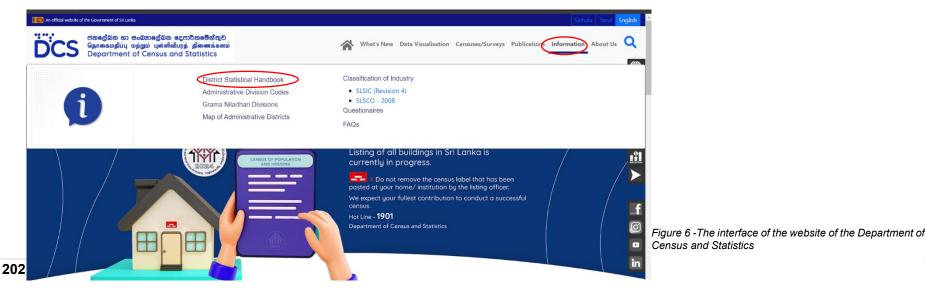
Population density is a critical factor in land use prediction because it directly influences the demand for various types of land use. High population densities typically require more residential, commercial, and infrastructure development to support the needs of the population. This often leads to increased urbanization, with more land being allocated for housing, businesses, transportation networks, and public services. Consequently, urban planners and policymakers use population density data to forecast and plan for future land use needs, ensuring that adequate resources and spaces are available to accommodate growth.

To create this layer, first, gather population or population data on a secondary data source. Since data is available for DSDs, we divide our study area for DSDs as well.

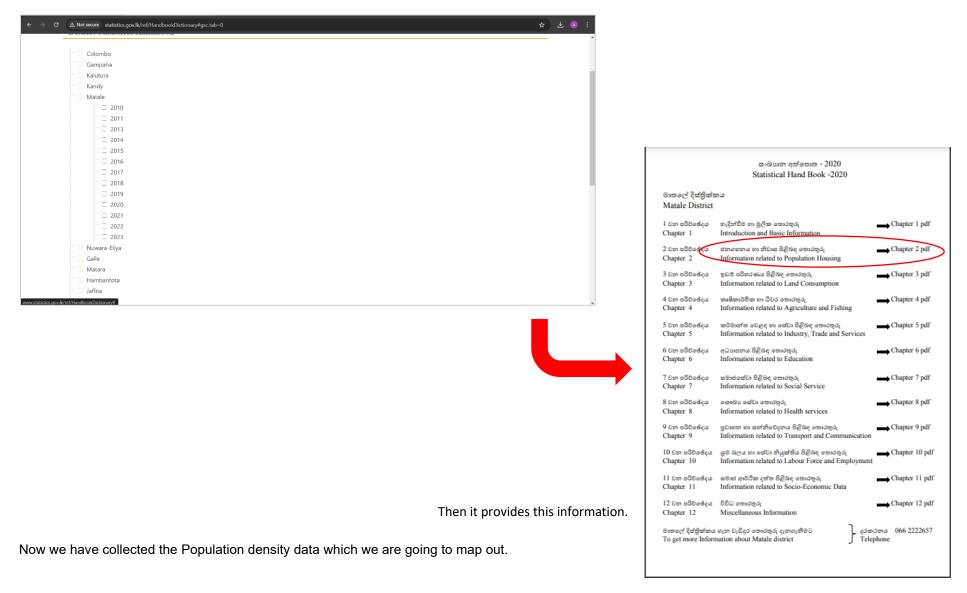
01. Gather Data from the Department of Census website



Go to Information>>District statistical handbook.



Extract the Name of the District and select the year in which we are going to collect data.

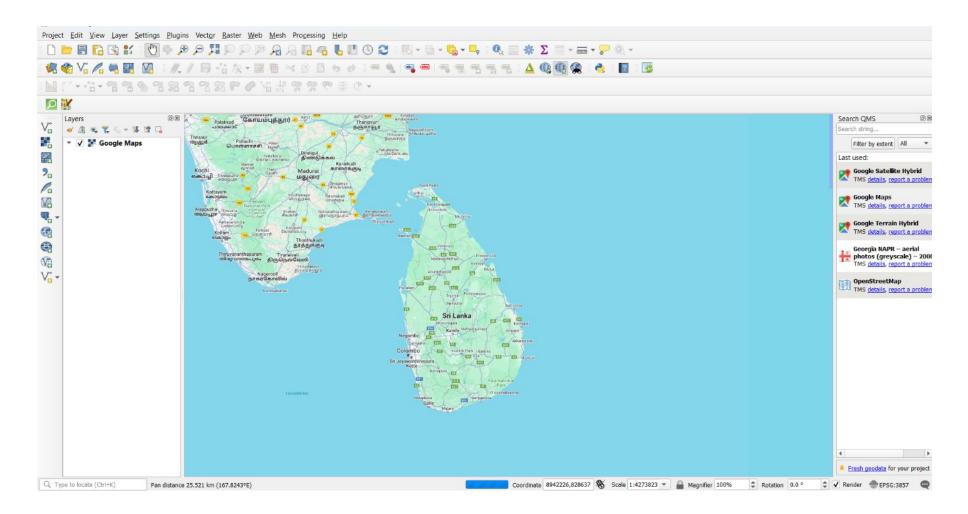


	ජනගහනය- Population				
පුාදේශීය ලේකම් කොට්ඨාසය D.S. Division	නාගරික Urban	ගාමීය Rural	වතු Estate	එකතුව Total	
ගලේවෙල Galewela		75,322	182	75504	
දඹුල්ල Dambulla	25,671	52,274	-	77945	
නාඋල Naula		29,130		29130	
පල්ලේපොල Pallepola		31,262	609	31871	
යටවත්ත Yatawatta	-	31,061	1,539	32600	
මාතලේ Matale	38,251	41,599	852	80702	
අಪಿಶುಂಖ ಜಾನೆಂದಂ Ambanganga Korale		14,066	2,797	16863	
ලග්ගල පල්ලේගම Laggala Pallegama		17,058	158	17216	
විල්ගමුව Wilgamuwa		31,794		31794	
රත්තොට Rattota		47,430	7,929	55359	
උකුවෙල Ukuwela	1,054	65,778	6,500	73332	
එකතුව - Total	64976	436774	20566	522316	

Now that we have the data for the population density, we can create the population data layer.

02. Import population density data to QGIS

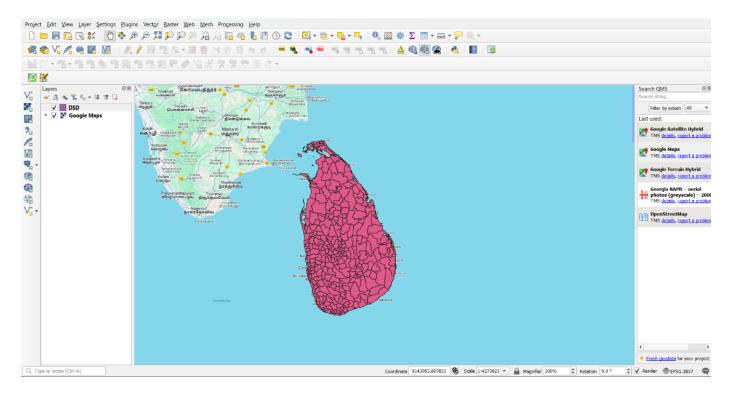
Open QGIS and add a base map to it.



Add a DSD (Divisional secretariat divisions) layer of Sri Lanka

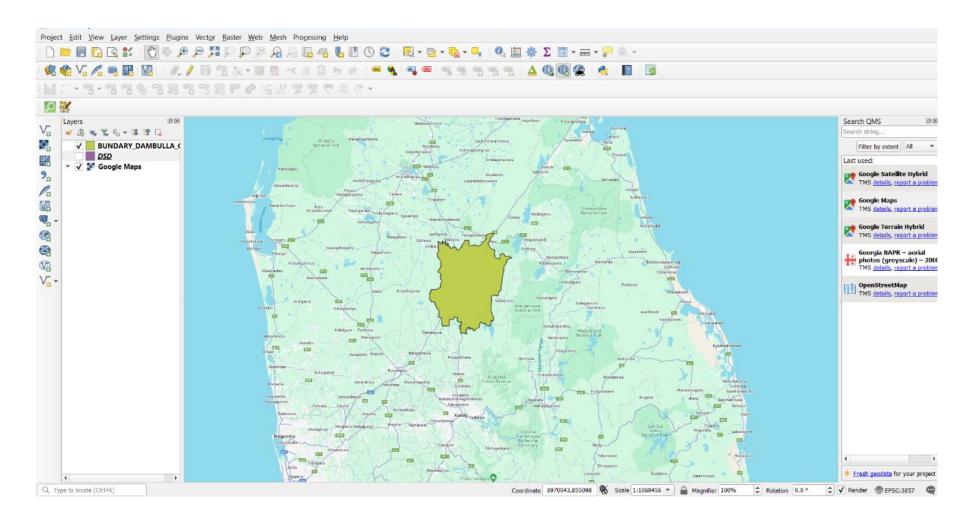
After clicking on "Layer", the following window will open. Then, go to the relevant folder and select the vector file. Usually, a shape file consists of 6 other files. The file type you should choose to open here is the "AutoCAD Shape Source" file. As per the instructions, click on that layer, and after that click on "Open". (For this you must have the relevant file.)

Go to Layer > Add Layer > Add Vector Layer > Browse



03. Add a layer to the study area.

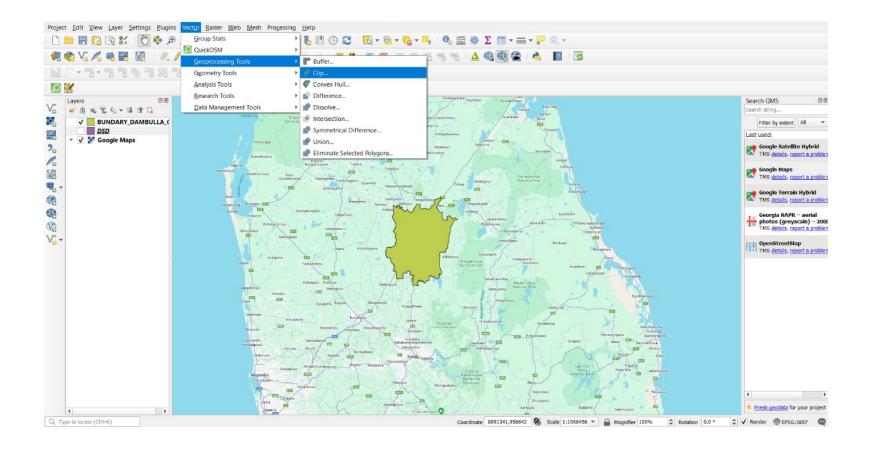
Go to Layer > Add Layer > Add Vector Layer > Browse



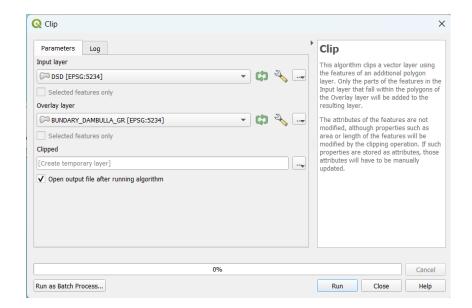
04. Run the Clip Tool.

Clip the DSD layer and the Boundary layer of the Greater Dambulla.

Go to Vector > Geoprocessing Tools > Clip

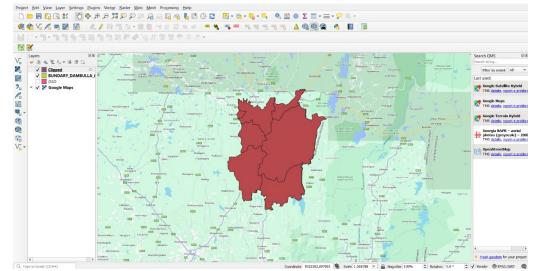


- I. Select the DSD Layer as the Input layer.
- II. Select the Boundary layer of the study area as the Overlay layer.



III. After setting the parameters, click "**Run**" to run the Clip tool. The tool will process the data and create a new clipped layer based on the boundary you provided.

This is the clipped output.



05. Create and update the Population density field

Open the attribute table of the layer. For that, **right-click on the layer > Open attribute table**

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ab	$abc PROVINCE_N = \mathcal{E}$ abc										
	PROVINCE_N	DCODE	DIST	CODE	DIVISEC						
1	ntral Province 🛛	11	ANURADHAPU	1115	PALUGASWEWA						
2	North Central Pr	11	ANURADHAPU	1116	KEKIRAWA						
3	North Central Pr	11	ANURADHAPU	1117	IPALOGAMA						
4	North Central Pr	11	ANURADHAPU	1119	PALAGALA						
5	North Central Pr	12	POLONNARUWA	1203	HINGURAKGODA						
6	North Central Pr	12	POLONNARUWA	1204	ELAHERA						
7	Central Province	31	MATALE	3101	GALEWELA						
8	Central Province	31	MATALE	3102	DAMBULLA						
9	Central Province	31	MATALE	3103	NAULA						
10	Central Province	31	MATALE	3104	PALLEPOLA						
11	Central Province	31	MATALE	3106	MATALE						

Add a new Field for Population Density.

For that, click on the **Toggle editing tool**.

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abc PROVINCE_N \checkmark = \mathcal{E} abc									
	PROVINCE_N	DCODE	DIST	CODE	DIVISEC				
1	North Central Pr	11	ANURADHAPU	1115	PALUGASWEWA				
2	North Central Pr	11	ANURADHAPU	1116	KEKIRAWA				
3	North Central Pr	11	ANURADHAPU	1117	IPALOGAMA				
4	North Central Pr	11	ANURADHAPU	1119	PALAGALA				
5	North Central Pr	12	POLONNARUWA	1203	HINGURAKGODA				
6	North Central Pr	12	POLONNARUWA	1204	ELAHERA				
7	Central Province	31	MATALE	3101	GALEWELA				
8	Central Province	31	MATALE	3102	DAMBULLA				

Add a new field as follows. Then you can see the menu like below you can enter the Field name and adjust the length of field characters.

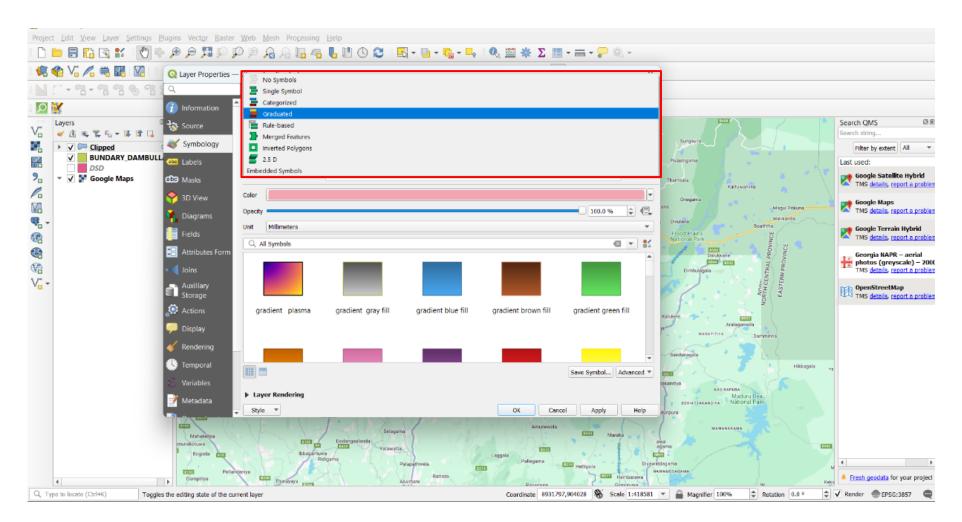
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abc PROVINCE_N ▼ =				New field	(Ctrl+W)
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1	North Central Pr	11	ANURADHAPU	1115	PALUGASWEWA
2	North Central Pr	11	ANURADHAPU	1116	KEKIRAWA
3	North Central Pr	11	ANURADHAPU	1117	IPALOGAMA
4	North Central Pr	11	ANURADHAPU	1119	PALAGALA
5	North Central Pr	12	POLONNARUWA	1203	HINGURAKGODA
6	North Central Pr	12	POLONNARUWA	1204	ELAHERA
7	Central Province	31	MATALE	3101	GALEWELA
8	Central Province	31	MATALE	3102	DAMBULLA

Now the new field will be added to the attribute table. Complete the Population Density column using collected data and save the changes.

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	PROVINCE_N	DCODE	DIST	CODE	DIVISEC	POP_Density			PROVINCE_N	DCODE	DIST	CODE	DIVISEC	POP_Density
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2	North Central Pr	11	ANURADHAPU	1116	KEKIRAWA	NULL		2	North Central Province	11	ANURADHAPU	1116	KEKIRAWA	195
3	North Central Pr	11	ANURADHAPU	1117	IPALOGAMA	NULL		3	North Central Province	11	ANURADHAPU	1117	IPALOGAMA	288
4	North Central Pr	11	ANURADHAPU	1119	PALAGALA	NULL		4	North Central Province	11	ANURADHAPU	1119	PALAGALA	165
5	North Central Pr	12	POLONNARUWA	1203	HINGURAKGODA	NULL	7	5	North Central Province	12	POLONNARUWA	1203	HINGURAKGODA	100
6	North Central Pr	12	POLONNARUWA	1204	ELAHERA	NULL		6	North Central Province	12	POLONNARUWA	1204	ELAHERA	136
7	Central Province	31	MATALE	3101	GALEWELA	NULL		7	Central Province	31	MATALE	3101	GALEWELA	404
8	Central Province	31	MATALE	3102	DAMBULLA	NULL		8	Central Province	31	MATALE	3102	DAMBULLA	176
9	Central Province	31	MATALE	3103	NAULA	NULL		9	Central Province	31	MATALE	3103	NAULA	106
10	Central Province	31	MATALE	3104	PALLEPOLA	NULL		10	Central Province	31	MATALE	3104	PALLEPOLA	393

06. Categorize according to the population Density.

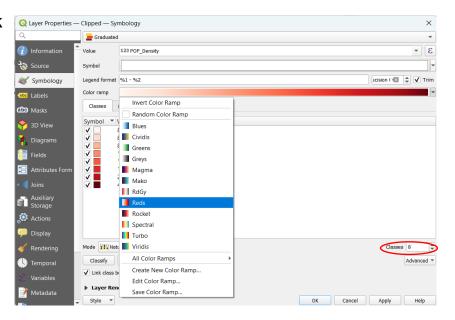
Right-click on the layer > Properties > Symbology > Graduated



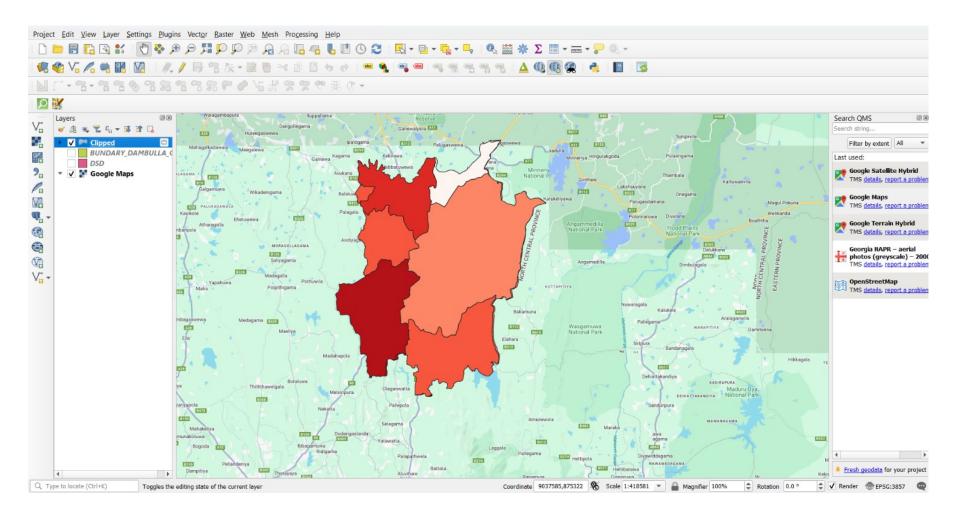
Select Pop_C	ensity as	the value.
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C Gradua	ied	
 Information Value 	123 POP_Density	•
Source Symbol		
Symbology Legend form	at %1 - %2	Precision 4 🗘 🗸 T
Labels Color ramp		
Classes Classes	Histogram	
Symbol	Values Legend	
Magrams		
Fields		
Attributes Form		
• Joins		
Auxiliary		
Storage		
Storage Actions		
Actions	qual Count (Quantile) 🔻	Classes 5
 Actions Display 	iqual Count (Quantile) >	Classes 5 Advance

Select the appropriate color ramp and **number of classes > Classify > Apply > OK**



This is the output vector layer for the population density of the Dambulla area.



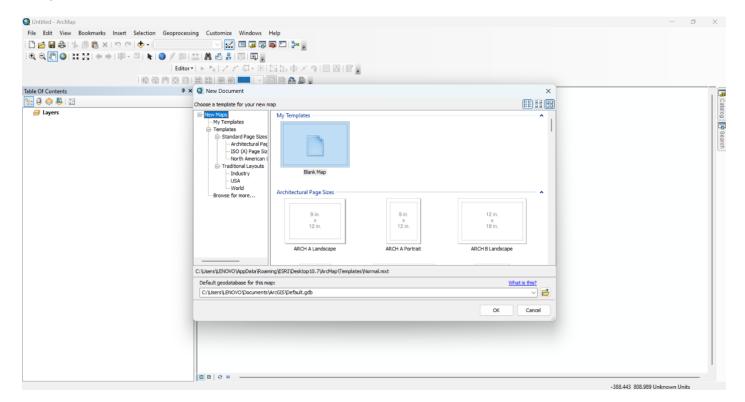
As mentioned in the first part of this document, this vector layer should be converted to a raster layer using QGIS or ArcMap. After that, if the cell size, row, and column values are not the same, the resampling process should be done.

6. Access to services

Conducting an access to services analysis is essential for identifying gaps in service delivery, improving accessibility, and ensuring equity. This analysis helps in efficient resource allocation, strategic planning, and informed policy-making. It also enhances service quality through user feedback, ensures compliance and accountability, and fosters community engagement and empowerment. Also, it provides economic and social benefits, supports benchmarking and best practices, and establishes a framework for ongoing monitoring and evaluation. Overall, it ensures services effectively meet the needs of all community members, promoting social cohesion and stability.

1. Open Arc GIS

New maps > Blank map > OK

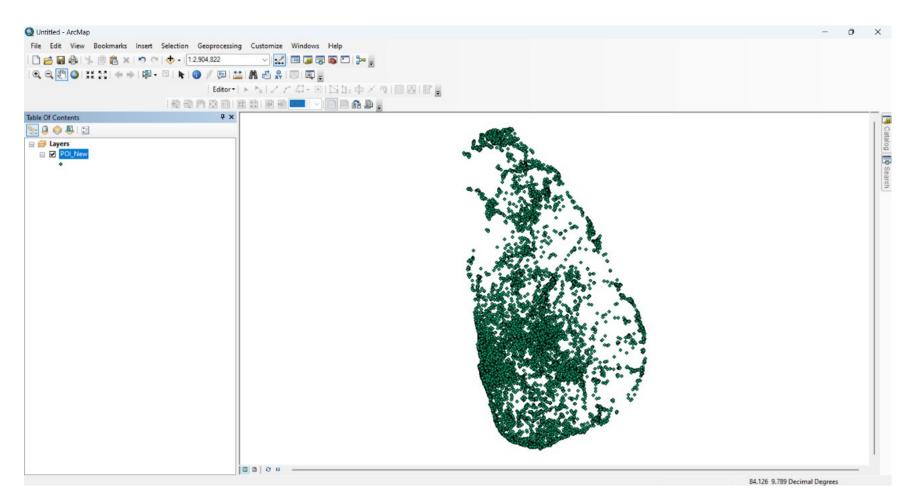


2. Add Shapefiles to the Map

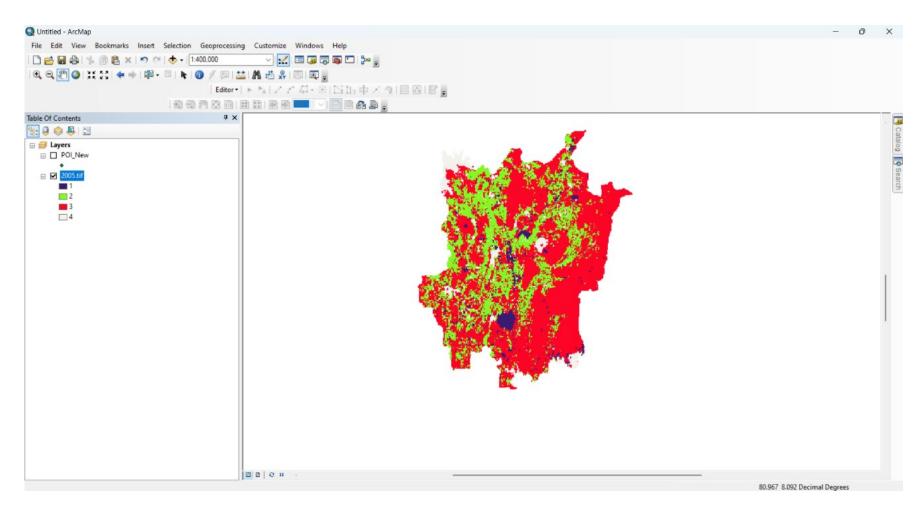
i. Navigate and select POI data.

How to download POI data:(Refer 15 min city book)

Go to File > Add Data > Add Data > Select POI data > Add > OK



ii. Add land use layer (2005) to the ArcMap. (The 2005 land use raster layer is needed because the raster file that is being created now wants to follow the same pixel size of the land use layer.



Go to File > Add Data > Add Data > Select Land use layer (2005) > Add > OK

3. Clip the POI data layer with the Land use layer.

Search for the clip (Analysis) for this step.

- Input features POI data layer. i.
- Clip features Layer of the boundary of the study area. ii.

Q 1 - ArcMap

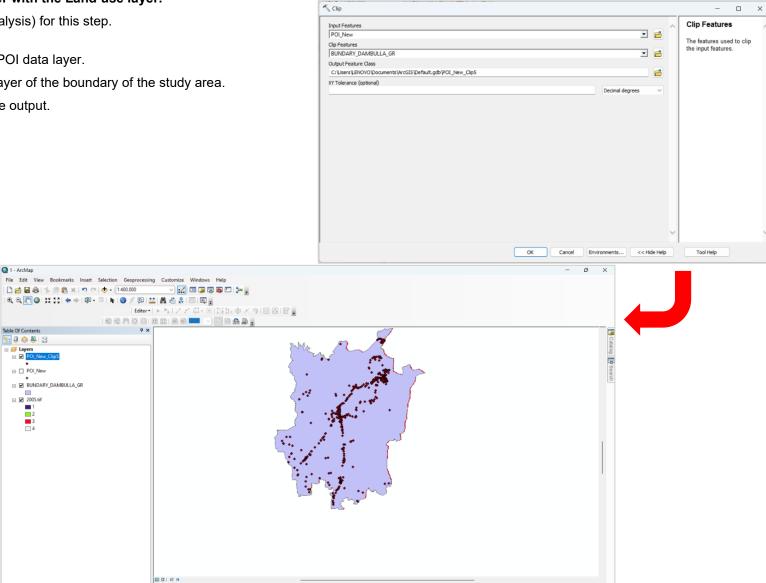
Table Of Contents

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POI_New

🖃 🗹 2005.tif 1 2 3 4

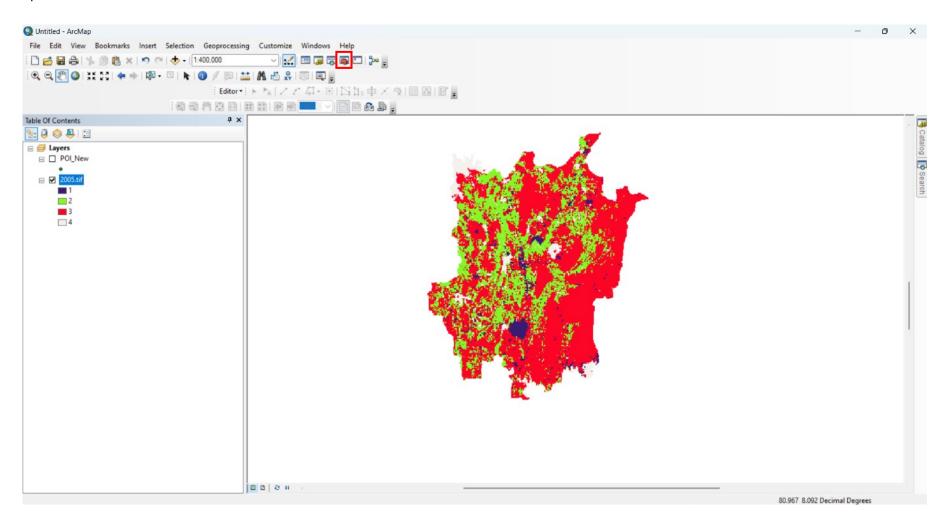
- Give a path for the output. iii.
- Click "OK" iv.



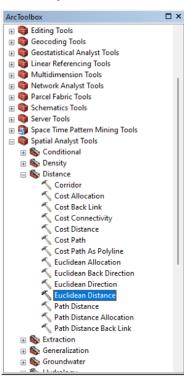
80.221 7.947 Decimal Degrees

4. Run the Euclidean Distance tool.

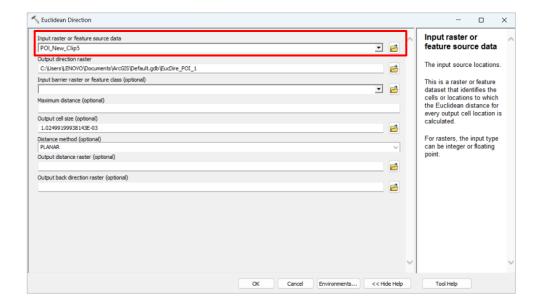
Open ArcToolBox.



Go to Arc Toolbox > Spatial Analyst Tools > Distance > Euclidean Distance



i. Input the Clipped POI data layer as input raster here.



ii. Go to the environment setting and set the following.

Workspace: Set the current and scratch workspace.

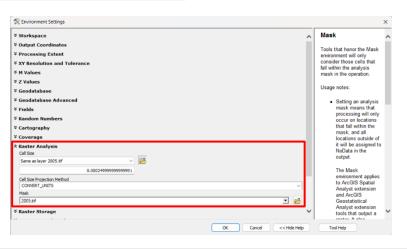
Processing Extent: Set to the same as your land use layer.

Raster Analysis Settings:

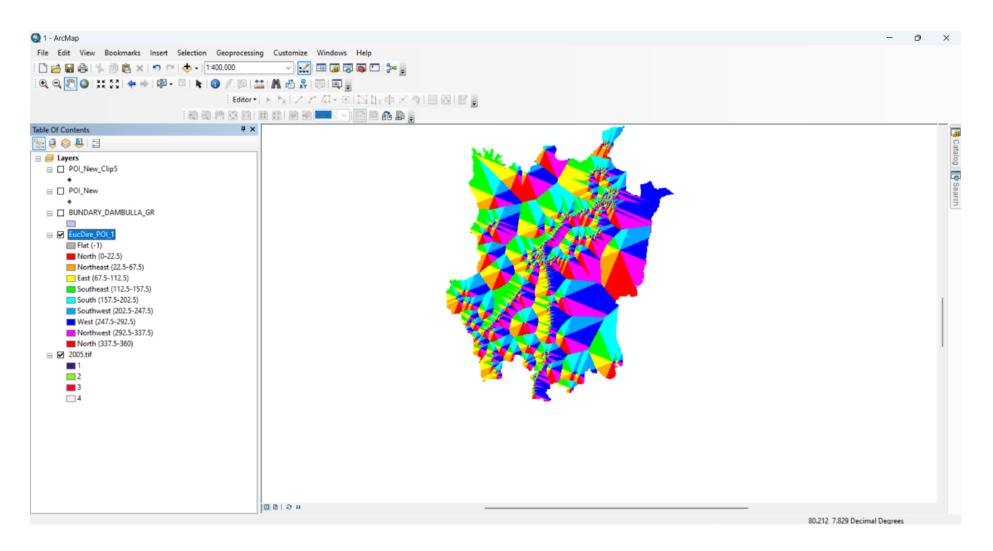
Cell Size: Set the cell size (pixel size) to match the resolution of your land use layer.

Mask: Set the mask to your land use layer to ensure the output raster matches the area of interest.

🙊 Environment Settings	×	🛠 Environment Settings	×
% Workspace Current Workspace Stratch Workspace Stratch Workspace Current Units operating the strategy of the s	Environment Settings Environment settings specified in this dialog box are values that will be used	Workspace Vourput Coordinates * Processing Extent Extent Same as layer 2005.1f	Extent The Extent environment setting defines what features or rasters will be processed by a tool. It is
	by tools that honor the serviconvert. They can be set hierarchically, meaning that they can be set for the application you are working in, so they apply to all rocks apply to all processes within the model, or for a particular process within a for a process within a model will override all other settings. Environments set for all processes in a model will override those set in the application.	Top 8.068909 Left 80.497750 Bottom 80.855250 Bottom 7.637659 Snap Raster Image: Constraint of the constrai	useful when you need to process only a portion of a larger dataset. You can think of this setting as a rectangle used to select input features and rasters for processing. Any feature or raster that passes be propulsed and written to outpat. Note that the rectangle is used only to select features, not clip them. The extent of the output ditaset will typically be larger than the Extent setting to account for features that pass through the extent rectangle.
X Raster Storage Geostatistical Analysis Parallel Processing X Remote Processing Server OK Cancel < <hde help<="" td=""><td>environment settings are additional parameters that affect a tool's results. They differ from normal tool parameters in that they Tool Hep</td><td>S Random Numbers Cartography Coverage X Partice Enclose OK Cancel <<hide hep<="" p=""></hide></td><td>Options: • Default—The tool voir are rising will Tool Help</td></hde>	environment settings are additional parameters that affect a tool's results. They differ from normal tool parameters in that they Tool Hep	S Random Numbers Cartography Coverage X Partice Enclose OK Cancel < <hide hep<="" p=""></hide>	Options: • Default—The tool voir are rising will Tool Help



This is the final output.



5. Review the raster layer

Check whether the Coordinate system and Pixel size are the same for the land use layer by Layer properties.

Right Click on the layer > Properties

roperty	Value			Property	Value		
Raster Information				XY Coordinate System	GCS_WGS_1984		
Columns and Rows	1430, 1725			Linear Unit			
Number of Bands	1			Angular Unit	Degree (0.0174532925199433)		
Cell Size (X, Y)	0.00025, 0.00025			Datum	D_WGS_1984		
Uncompressed Size	4.70 MB			Vertical Coordinate Sy	ste		
Format	FGDBR			Statistics			
Source Type	Generic			Band_1			
Pixel Type	signed integer			Build Parameters			_
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			The second secon				-
		Set Data Source				Set Data Source	5

- Pixel size, row-column sizes, and coordinate systems are the same as the land use layer. So, no need to make any changes.
- By following these steps, you can make the "Access to service" raster layer.

7. Accessibility

Accessibility is a crucial spatial variable often used in land use change modeling, including in the MOLUSCE plugin. It refers to the ease with which different locations can be reached from a particular point, influencing land use patterns and development. High accessibility areas, such as those near roads, urban centers, or transportation hubs, are more likely to experience development and land use changes due to better connectivity and the movement of people and goods.

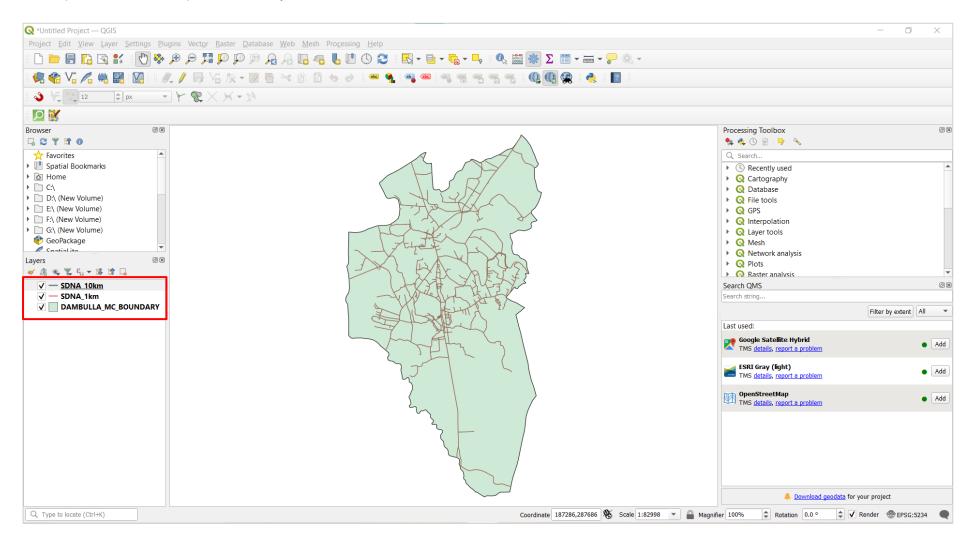
In the context of land use modeling, accessibility can be quantified by measuring distances to key infrastructure elements like roads, highways, city centers, or public transportation stations. This variable helps predict how proximity to these elements affects land-use transitions, such as urban expansion or agricultural development. By incorporating accessibility as a spatial variable, models like MOLUSCE can more accurately simulate and forecast future land use changes, aiding in effective planning and resource management. Here are the basic steps for how to create a raster layer for accessibility using the **Dambulla MC boundary**. Although we explain how to create this layer using a different area extent here, all spatial variables and land use layers should have the same area extent.

First, we have to prepare a sDNA layer using the current road network of the selected area. sDNA (Spatial Design Network Analysis) is a powerful tool used to analyze accessibility and connectivity within spatial networks, such as road systems. Also, it is a toolkit that integrates with GIS software to perform network analysis. It evaluates various metrics such as reach, betweenness, closeness, and straightness, which measure how easily different parts of a network can be accessed from any given point. These metrics help in understanding the flow of movement through a network, identifying key corridors, and predicting areas of potential development. This provides valuable insights into how the structure and connectivity of a road network influence land use patterns.

To prepare an sDNA layer for accessibility analysis using a current road layer, start by obtaining a clean, topologically correct vector road network layer, typically in shapefile format. Ensure the sDNA toolkit is installed and configured in your GIS software (e.g., QGIS or ArcGIS). Then, preprocess the road layer to remove any gaps, overlaps, or disconnected segments, and simplify the network if necessary to streamline the analysis.

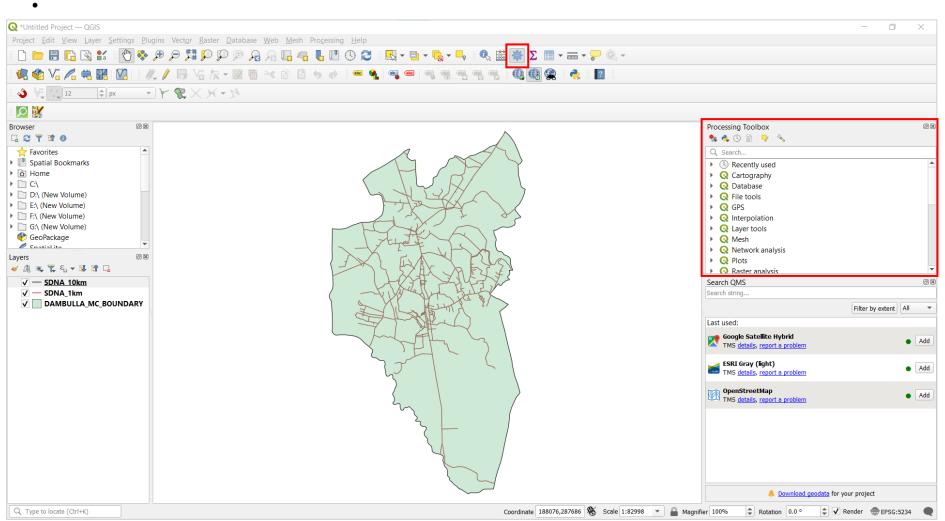
Next, define the parameters for the sDNA analysis, such as the radius of analysis and specific metrics like betweenness and closeness. Run the sDNA tool on the road layer to calculate these accessibility metrics. The output will be a new layer containing these metrics for each road segment, which can be used as input in the MOLUSCE plugin to model the influence of accessibility on land use changes. We have to ensure this sDNA layer aligns correctly with other spatial data layers to validate the results.

Next, open the QGIS and input the boundary, and sDNA data to the interface.



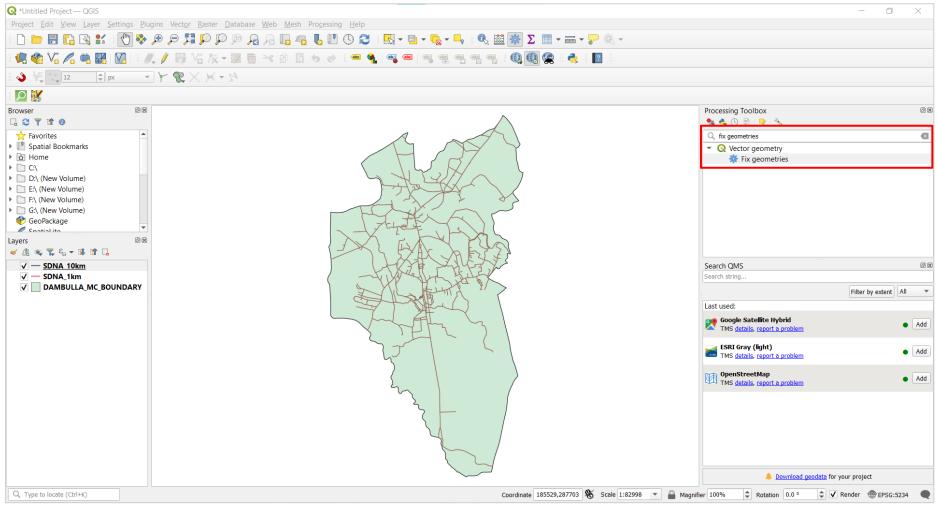
Converting the line feature into points

• First, we have to fix the geometries. For that, click on the processing toolbox and it will open the processing toolbox menu.



• Now type the "fix geometries" in its search bar.

- So, the fix geometries tool will appear under the menu, and double-click on it.
- Then the fix geometries window will appear and select one of the SDNA layers from the drop-down menu of the input layer. (In this book we have used the

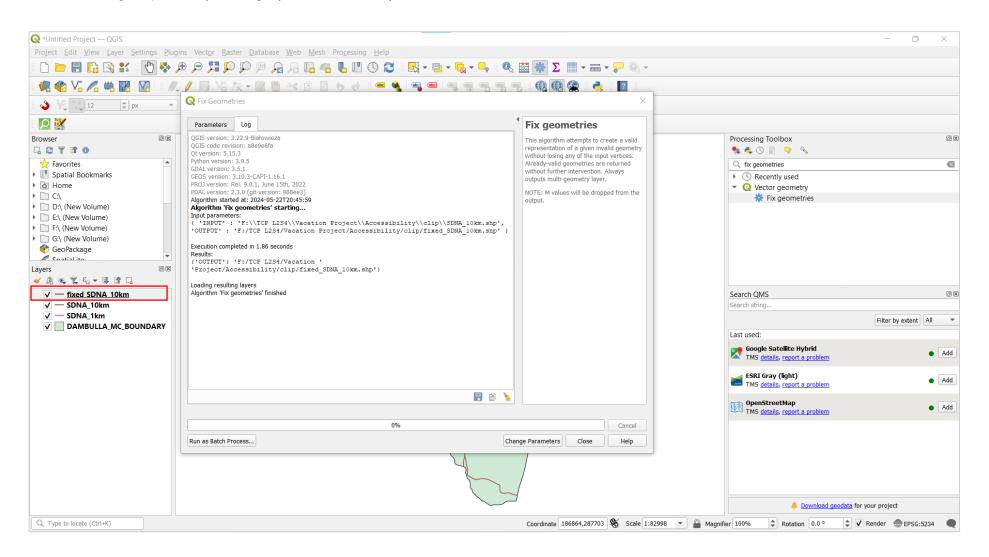


sDNA_10km layer first)

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- Click save to file and save your fixed sDNA layer into a folder. Then click on run.

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• After running the process, you can get your fixed sDNA layer like below.

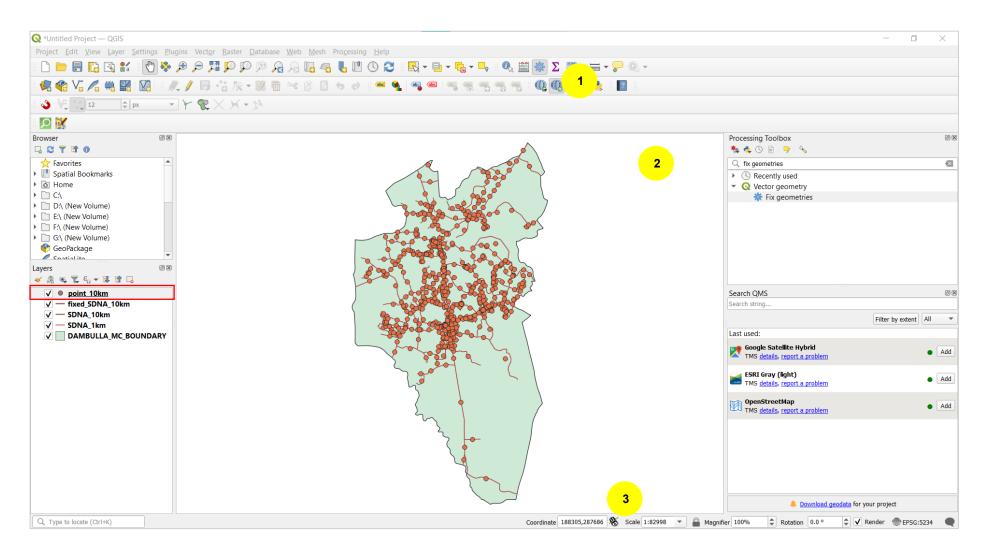


- Next, click on the vector tab.
- Select geometry tools and click on centroids in there.

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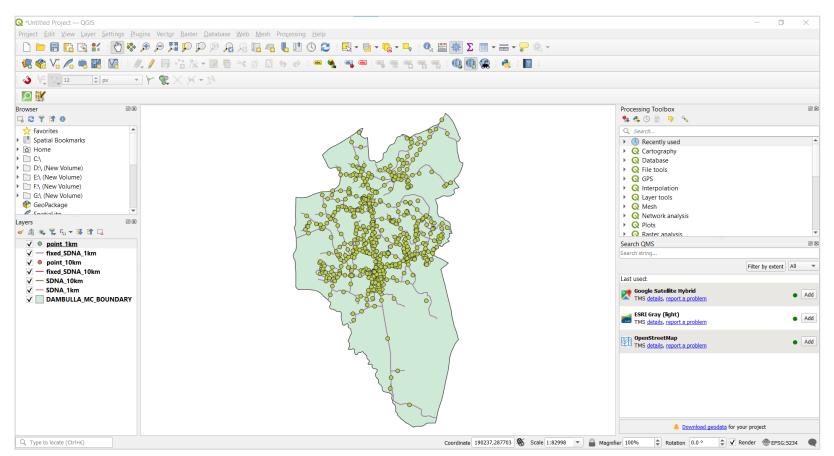
• It will open the centroids window and select the fixed sDNA_10km layer from the drop-down menu in the input layer.

- Save the file in a relevant folder and click on run. (In there we saved the new centroid layer as point_10km)
- After running the process, you can get the point layer for the sDNA dataset.



- Following the same process in the above steps, you can fix geometries and then convert the line feature into points in the sDNA_1km layer.
- So, after that, you can get the point layer for both sDNA_10km and sDNA_1km layers. Those point layers are used for the interpolation and creation of raster

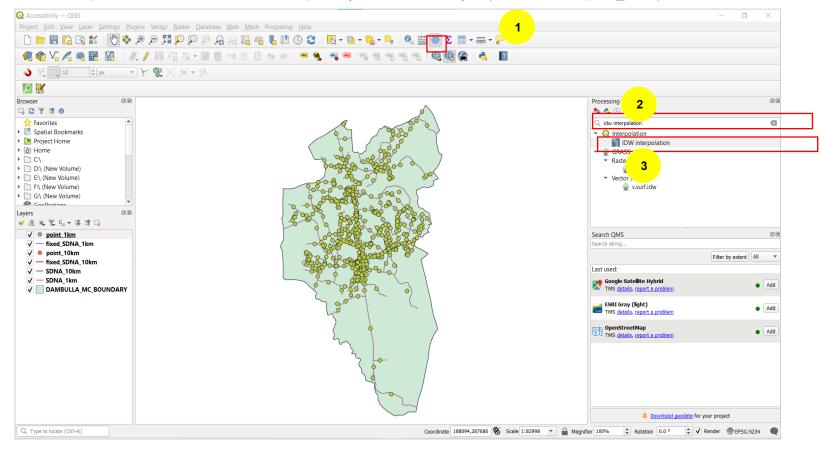
layers.



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Running the IDW interpolation tool

- Click the processing toolbox in the ribbon
- Type IDW interpolation in the search bar of the processing toolbox menu
- The relevant tool will appear under the menu and double-click the IDW interpolation.
- In the IDW interpolation window, select the relevant point layer as the vector layer. (In this book it is point_10km)



- Select the interpolation attribute as NQPDA10000 in the drop-down menu and click the plus mark below.
- In the extent, select calculate from layer and then click on your relevant boundary. In this book, the extent is the Dambulla MC boundary.
- Then save the interpolated layer to a file on your desktop and click on run to process.

🔇 *Accessibility — QGIS			– 0 X
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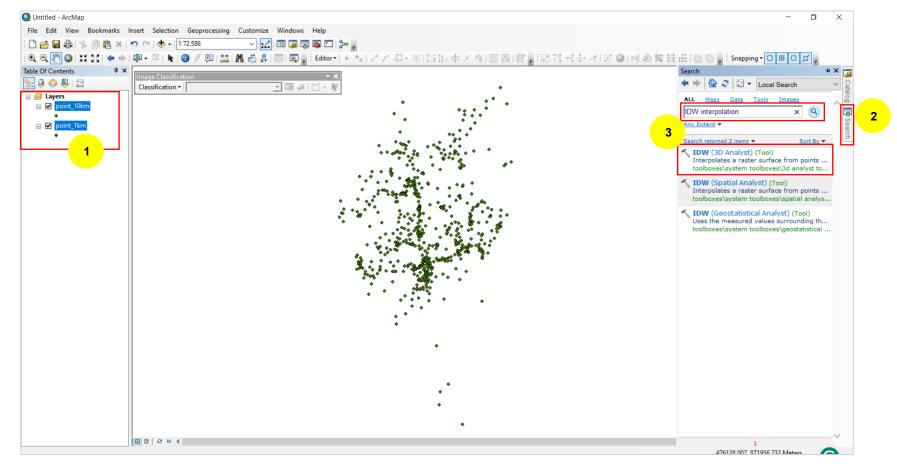
But most probably, we encountered an error in the process of interpolation with the QGIS as follows.

🔇 IDW Interpo	lation			×
Parameters	Log		4	IDW interpolation
PDAL version: 2. Algorithm starte Algorithm 'IDV Input parameter { 'DISTANCE '183153.2355 'INTERPOLATI point_10km.; Accessibilit	ion: a8e .3 3.9.5 .5.1 .10.3-C el. 9.0.1 .3.0 (git d at: 20 V inter S: _COEFF 500000 CON_DA shp::~ cy/cli after 87 g layers	e6fa PI-1.16.1 June 15th, 2022 rersion: 988ee3) 4-05-23T23:29:55 Jation' starting CIENT' : 2, 'EXTENT' : 190262.684900000,287999.516400000,301142.935700000 [EPSG:5234]', A' : 'F:/TCP L2S4/Vacation Project/Accessibility/clip/ :0::~::8::~::0', 'OUTPUT' : 'F:/TCP L2S4/Vacation Project/ /interpolate_10km.tif', 'PIXEL_SIZE' : 0.1 } 20 seconds (1 minute 28 seconds)		Generates an Inverse Distance Weighted (IDW) interpolation of a point vector layer. Sample points are weighted during interpolation such that the influence of one point relative to another declines with distance from the unknown point you want to create.
		0%		Cancel
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Optional Steps

Because of the error encountered in the QGIS, we have done the interpolation process using Arc Map. For that,

- First, input the point layers into the Arc Map interface.
- Click on the search tab and it will appear the search menu of tools.
- Then type the IDW interpolation in the search bar and click the search icon.
- After searching for the tool, the list of tools will appear under the menu, and select the IDW interpolation (3D Analyst) tool.



- It will open the IDW tool window and in there select your relevant point layer as the input point features.
- Select NQPDA 10000 as the z-value field in the drop-down menu.
- Keep output raster as default and click on environments.

N IDW					>	<
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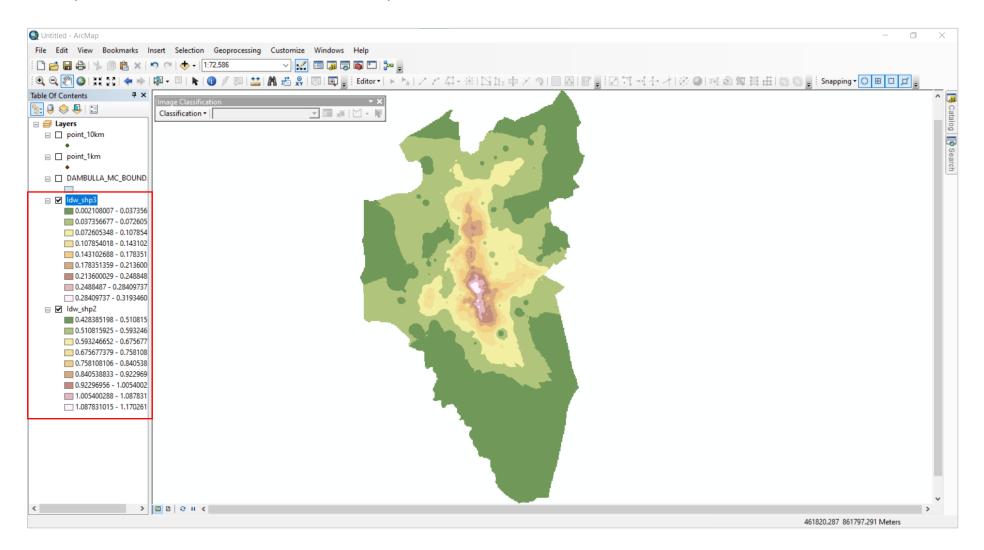
- It will open the environment settings window and select the processing extent in there.
- Select your relevant boundary layer as the extent.
- Then click on the raster analysis drop-down menu to open it.
- In raster analysis, select your boundary layer as the mask option and click ok.

Revironment Settings ×	🛠 Environment Settings 🛛 🕹
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* M Values * Z Values * Geodatabase * Geodatabase Advanced * Fields * Random Numbers * Cartography * Coverage * Raster Analysis * Raster Storage OK Cancel Show Help >>	Extent Same as layer DAMBULLA_MC_BOUNDARY Top 301142.935727 Left Right 190262.684931 190262.684931 287999.516361 Snap Raster
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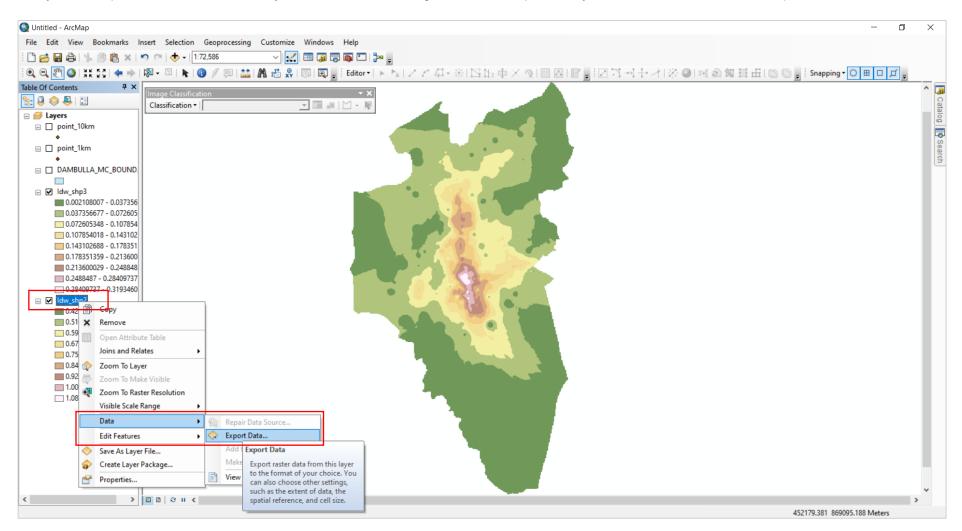
- Q Untitled ArcMap ٥ \times File Edit View Bookmarks Insert Selection Geoprocessing Customize Windows Help % 🖹 🖺 🗙 🔊 🍽 🔶 🛛 1:72,586 🗸 🔀 🗐 🖓 🖓 🔄 🎾 🖕 🗋 📂 🔚 🖨 | 🔍 🔍 🕙 🥝 💥 🏹 🔶 🕨 |蹤・□| ▶| ④ 彡 ▣| 🏙| 離 過 Ձ| 圆| 圓 g| Editor+| ▶ ʰ, | ↗ ↗ 尋・米| 凶 炬 中 × ⑨| 目 Δ| ฮ g ! ↗ ゴ 寸 才 | ※ ◎| 呵 ゑ 剱 昌 田| ⑮ ◎ g ! Snapping+ ○ 田 ロ ゴ g Table Of Contents Ψ× Catalog I Search 🏡 📮 📚 📮 🗄 🔽 🗐 🐖 🖂 - 🦷 Classification • 🖃 *L*ayers 🖃 🔲 point_10km □ point_1km DAMBULLA_MC_BOUND 🖃 🗹 🛛 0.428385198 - 0.510815 0.510815925 - 0.593246 0.593246652 - 0.675677 0.675677379 - 0.758108 0.758108106 - 0.840538 0.840538833 - 0.922969 0.92296956 - 1.0054002 1.005400288 - 1.087831 1.087831015 - 1.170261 -> 🛛 🖻 😣 🖬 🖌 < 461685.852 861854.906 Meters
- After running the process, you can get the interpolated point layer of the 10km.

• So, you have to do the same process mentioned above optional steps for your other point layer and interpolate it to obtain a raster dataset. (In this book we have to interpolate the point_1km layer following the same process we have done to the point_10km layer)

• Now you have obtained two raster datasets for accessibility.



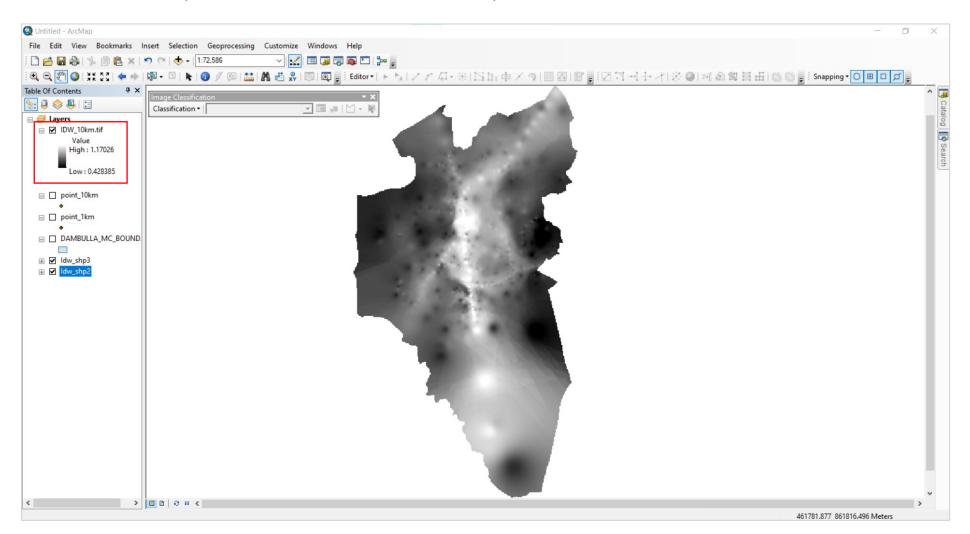
Now you can export them to a folder for easy identification. For that right-click the interpolated layer. Go to the Data and click on export data.



- Export raster data window will appear and in there select a relevant folder to select your data by clicking the folder icon.
- Then give the relevant name. In this book, we gave IDW_10km.
- Select the format as TIFF format.
- Then click on save.

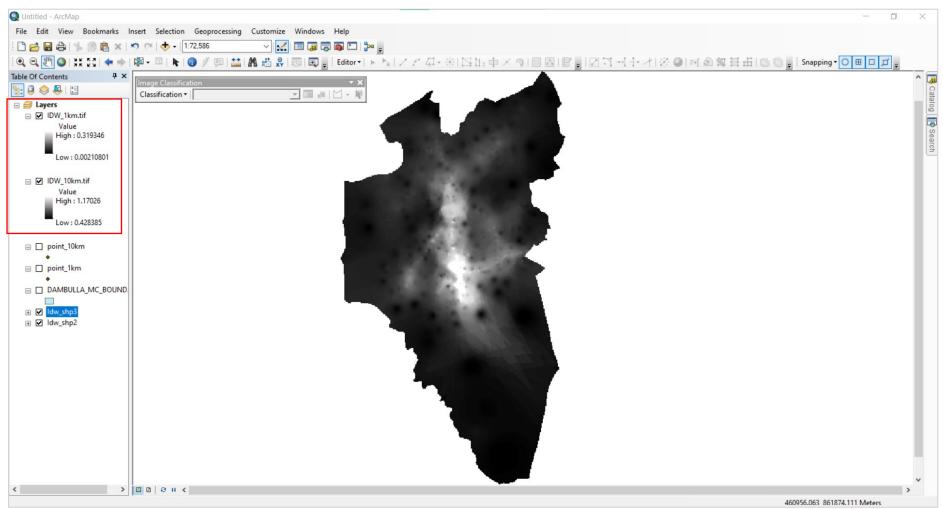
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• It will add a new raster layer to the interface and we can use it for further analysis in QGIS.



• Do the same process mentioned in steps 12 to 17 to save the other interpolated layer as well.

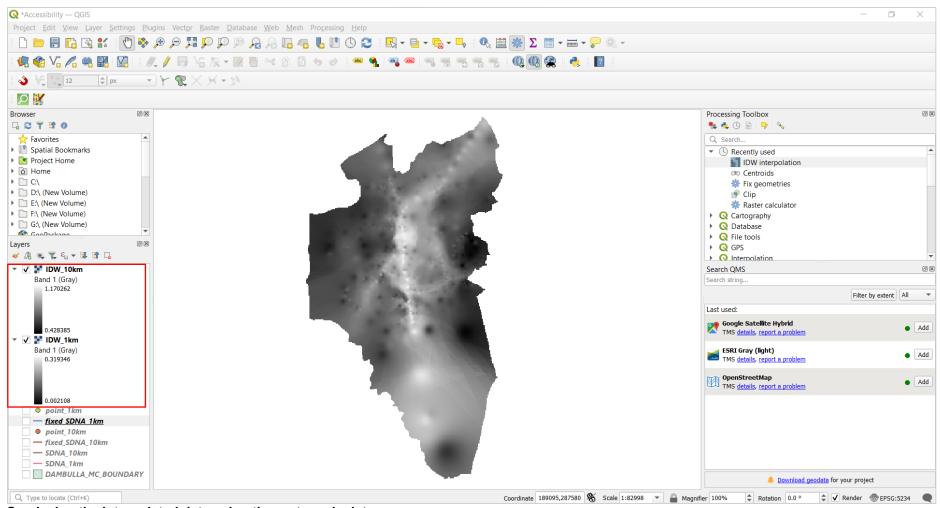
• Now you have the two interpolated layers which can be added to the QGIS interface.



Overlaying the two raster layers

• Again, we are moving to the QGIS. Then we add the above two raster layers into the QGIS.

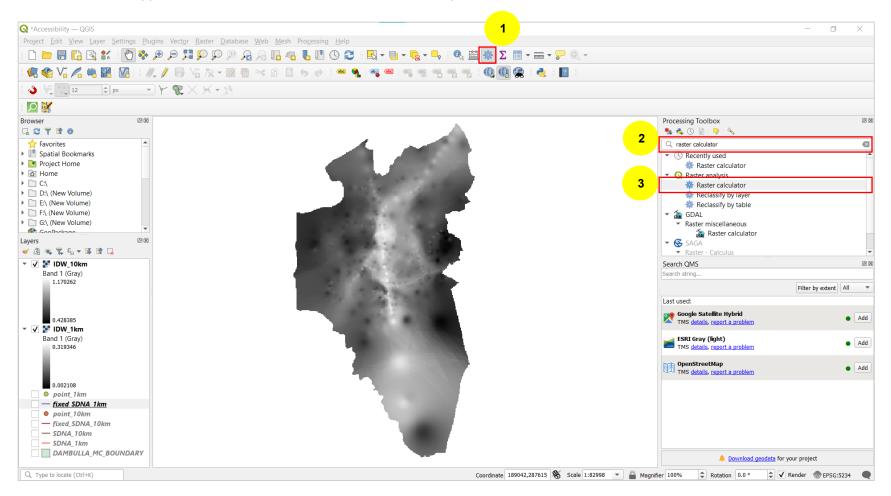
Now the interpolated data are added to the interface of QGIS.



Overlaying the interpolated data using the raster calculator

• Click on the processing toolbox icon.

- Type "raster calculator" in the processing toolbox's search bar.
- Once the relevant tool appears, double-click on the raster calculator tool to open it.



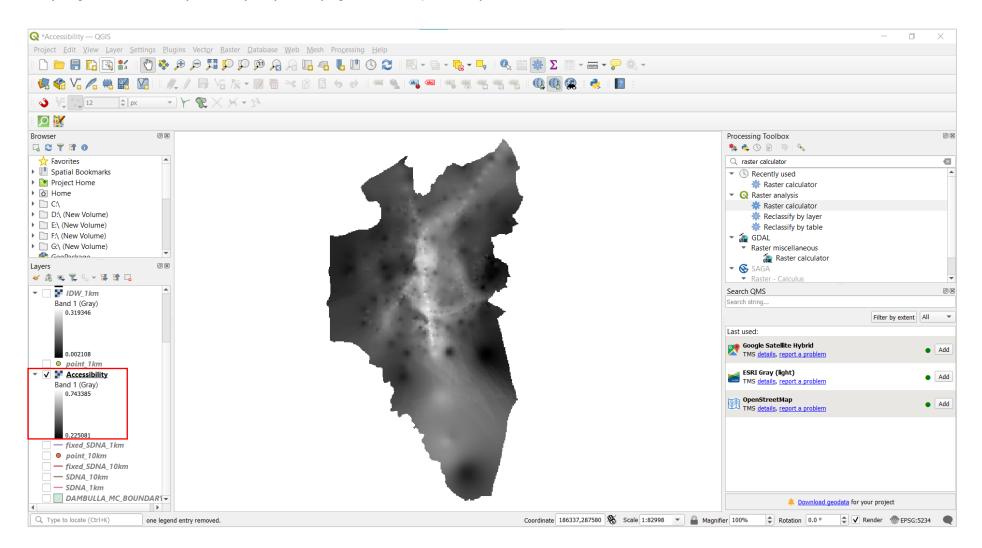
- In the raster calculator window, type the equation in the expression tab. (The two interpolated layers equally contribute to and influence the accessibility level. By dividing 100% influence equally to two we can consider **0.5** as the weight factor for these two layers as they equally contribute to the accessibility level. So, we have to multiply each layer from **0.5** to get the accessibility level)
- Then click on the three-dotted icon to select a reference layer.

Layers	perators	This algorithm allows performing algebraic operations using raster layers.	
IDW_10km@1 IDW_1km@1 IDW_1km@1 Expression (0.5*"IDW_10km@1")+	+ * cos sin log10 AND - / acos asin In OR ^ sqrt tan atan () < > = != <= >= abs min max	The resulting layer will have its values computed according to an expression. The expression can contain numerical values, operators and references to ar of the layers in the current project. Th following functions are also supported - sin(), cos(), tan(), atan2(), ln(), log10() The extent, cell size, and output CRS can be defined by the user. If the extent is not specified, the minimum extent that covers selected reference layer(si will be used. If the cell size is not specified, the minimum cell size of selected reference layer(s) will be used. If the output CRS is not specified the CRS of the first reference layer wi be used.	
Predefined expressions	Add Save	The cell size is assumed to be the same in both X and Y axes. Layers are referred by their name as displayed in the layer list and the number of the band to use (based on 1), using the pattern	
inputs selected	automated extent, cellsize, and CRS) [optional]	'Jayer_name@band number'. For instance, the first band from a layer named DEM will be referred as DEM@1	

- In the reference layer, select one of the layers and go back to the previous window. By accessing the reference layer, it will automatically assign the coordinate system, cell size, and output extent of the selected layer to the output layer.
- So, there is no need to change the other parameters in the raster calculator and select a relevant folder to save the accessibility raster file.
- Then click on run to overlay those two rasters.

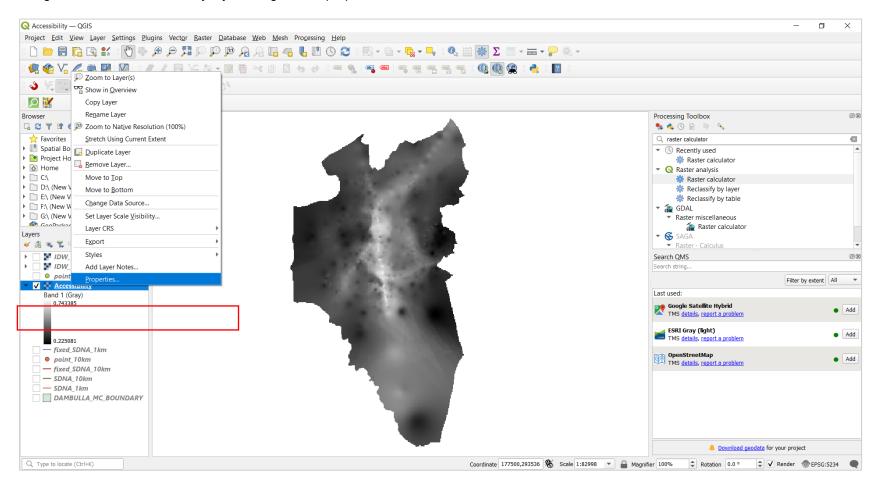
Q Raster Calculator			×		
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✓ IDW_10km [EPSG:32644]	Select All	algebraic operations using raster layers.			
IDW_1km [EPSG:32644]		The resulting layer will have its va	lues		
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	Add File(s)	following functions are also suppo	rted:		
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Run as Batch Process		Run Close	Help	1 inputs selected Cell size (use 0 or empty to set it automatically) [optional]	specified, the minimum cell si
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				Output CRS [optional]	in both X and Y axes.
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				Output	number of the band to use (b 1), using the pattern
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				✓ Open output file after running algorithm	named DEM will be referred a
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				Run as Batch Process	Run Close
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So, you got the accessibility raster layer by overlaying the two interpolated layers.



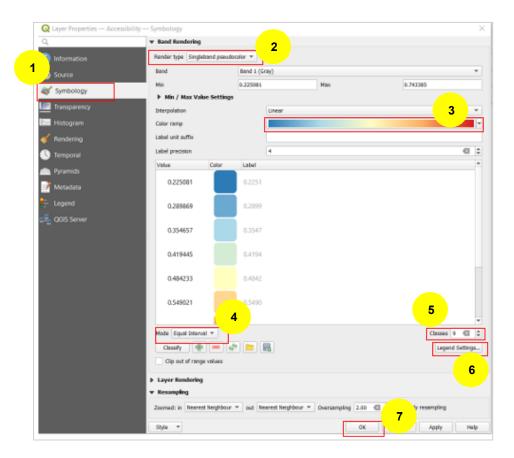
Get the accessibility raster layer

• Right-click on the accessibility layer and go to the properties.



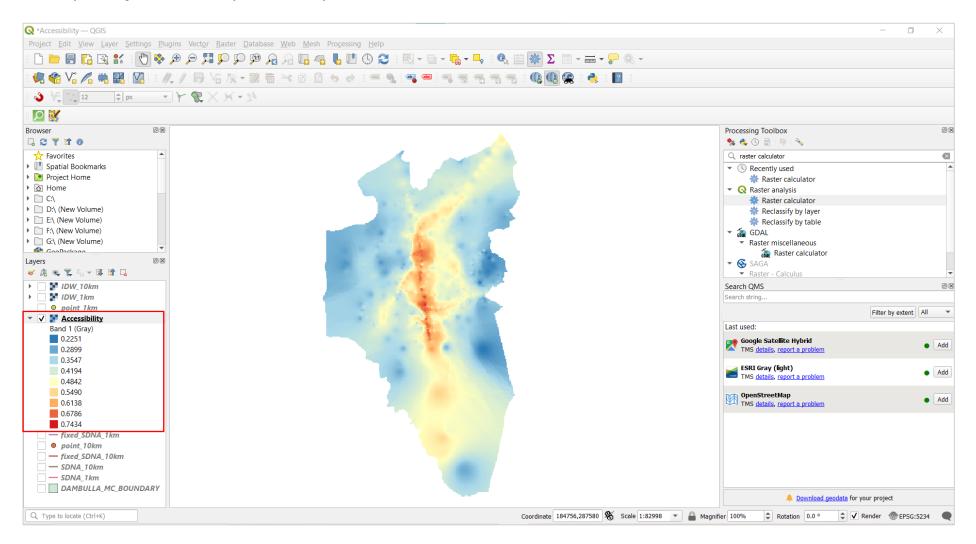
- Go to the symbology panel and select the render type as "singleband pseudocolor".
- Then select a relevant color ramp.

- Set "equal interval" as the mode.
- We can categorize accessibility into 9 classes, so type "9" in the classes.
- Then click on legend settings.
- In the legend settings window tick off the use continuous legend and click "OK".
- After applying all parameters click "Apply" and "OK".



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• Now you can get the accessibility level raster layer.



CHAPTER 3: MOLUSCE PLUGIN TO MODEL THE FUTURE LAND USE CHANGE

What is MOLUSCE?

MOLUSCE (Modules for Land Use Change Simulations), is a robust QGIS plugin meticulously designed to analyze and predict the future land use change within specific regions. Employing a suite of algorithms encompassing Artificial Neural Networks (ANN), Logistic Regression (LR), Weight of Evidence (WoE), and the Markov Chain Ensemble (MCE) method, MOLUSCE excels in simulating and evaluating land use alterations over time. By ingesting raster data representing historical and current land use categories alongside pertinent explanatory variables, including socio-economic factors, the plugin seamlessly conducts model training to forecast future land use changes. With applications spanning urban planning for evaluating urban growth and development, forestry for predicting alterations in forest cover, and environmental impact assessment, MOLUSCE emerges as an indispensable tool for comprehensive land use analysis and informed decision-making.

Modeling capabilities

MOLUSCE boasts extensive modeling capabilities by incorporating diverse driving factors crucial for understanding land use dynamics, including proximity to roads, distance to urban centers, slope, environmentally sensitive areas, land use efficiency, population density, etc. By integrating these factors into its predictive models, MOLUSCE accurately forecasts future land use changes based on the provided data. Furthermore, the plugin offers validation tools such as kappa statistics to evaluate the performance of these predictive models, ensuring reliability and accuracy in assessing and predicting land use transformations over time.

The maximum number of inputs for factors in the MOLUSCE plugin can vary depending on several factors, including the computational resources available and the complexity of the model being used. While there is no fixed maximum limit specified, MOLUSCE is designed to handle a wide range of input variables, allowing for a comprehensive analysis of land use changes. The actual maximum number of inputs may be determined by practical considerations such as available memory and processing power.

Compatibility and Installation

MOLUSCE is compatible with QGIS, specifically versions 2.0 and above. QGIS 2.18 is usually used for this purpose. This is open-source software, and after downloading the setup, you can install QGIS 2.18 on your computer in a few simple steps.

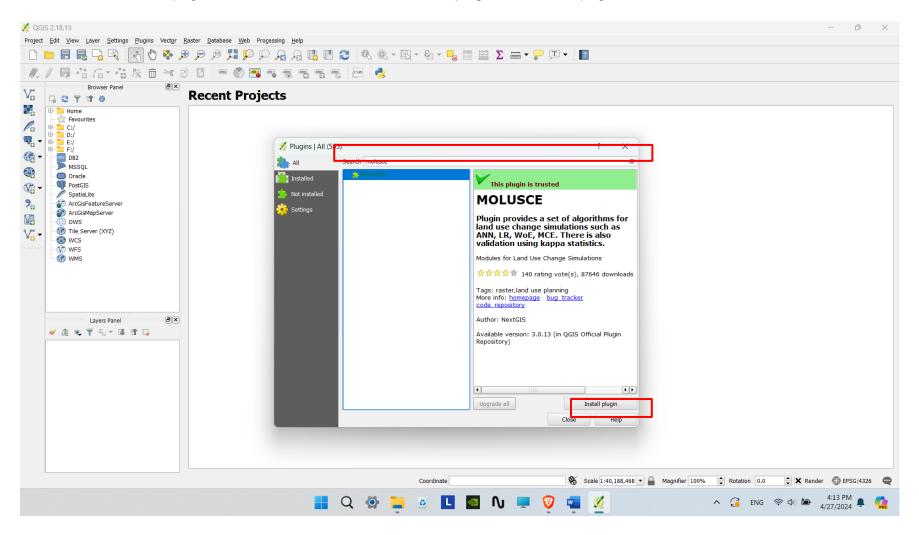


This version is compatible with Windows XP 64-bit, Vista 64-bit, Windows 7 64-bit, Windows 8 64-bit, Windows 10 64-bit, Windows 11 64-bit operating systems. While there are no strict formal requirements, it is recommended to have a minimum of 4 GB of RAM to ensure smooth operation, with additional RAM greatly enhancing processing speed, particularly for handling large datasets and complex analyses. While QGIS itself is not highly graphics-intensive, having a decent graphics card with OpenGL support can improve map rendering, 3D visualization, and overall system responsiveness, enhancing the user experience when utilizing MOLUSCE for comprehensive land use assessments and simulations.

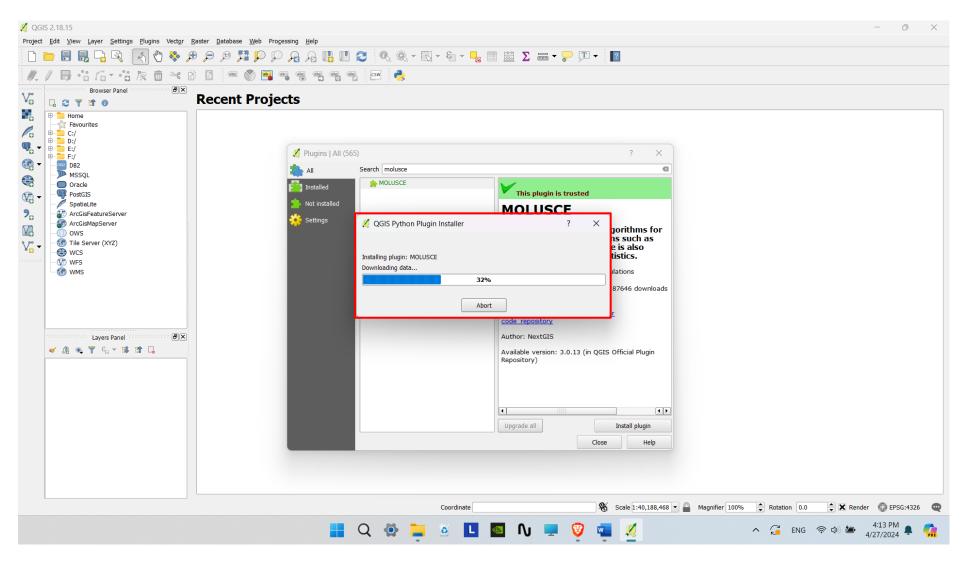
1. After installing QGIS 2.18.15, we have to install the **MOLUSCE plugin** separately. For that, open the QGIS software. The interface looks as follows. You can see the main toolbars in the left upper corner of the interface.

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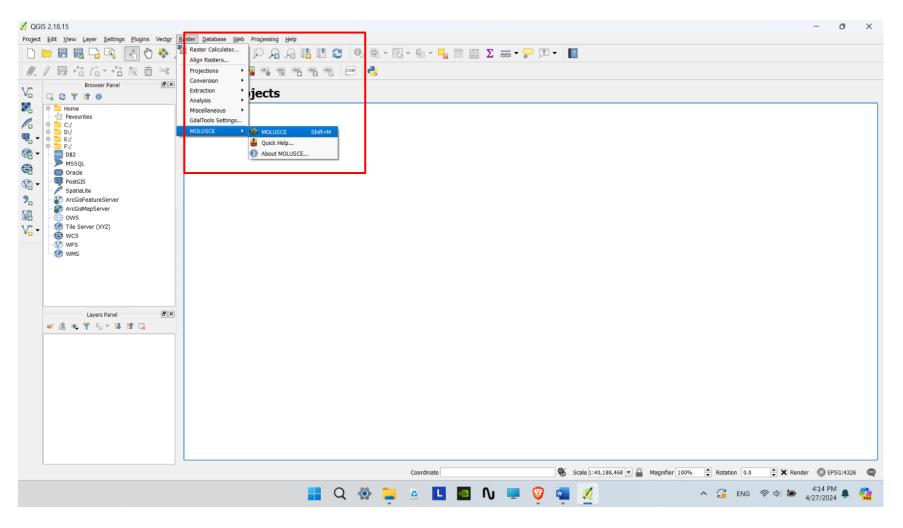
2. Next, we have to install the MOLUSCE plugin. For that, open the Plugins toolbar from the left upper corner, and search for the MOLUSCE plugin as follows. Then the plugin will be shown. After that, click on "**Install plugin**" to install this plugin.



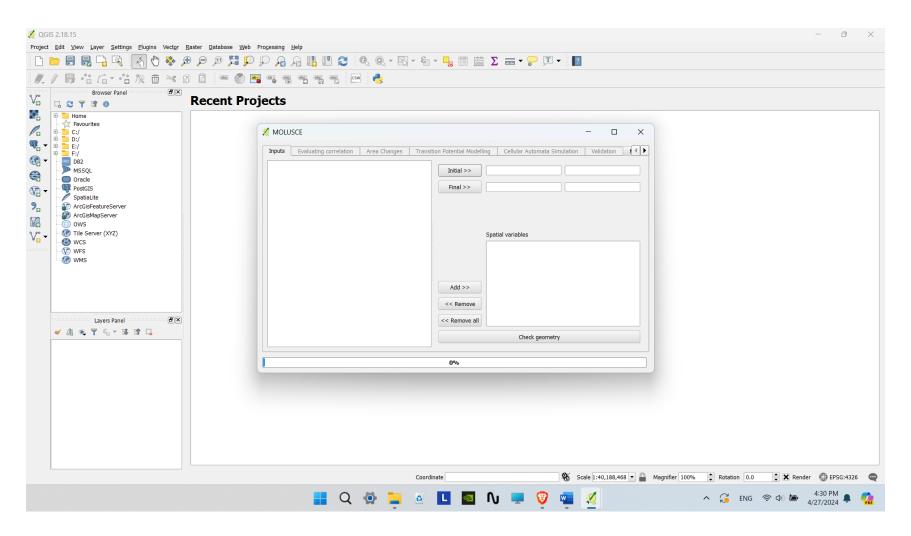
3. The installation process will be shown as follows. Once this process is complete, you can close the plugin's toolbar.



4. Now you can click on the Raster toolbar. It contains several tools and the MOLUSCE plugin as follows. Then again click on the "**MOLUSCE**". Finally, the plugin and its related tools will be shown.

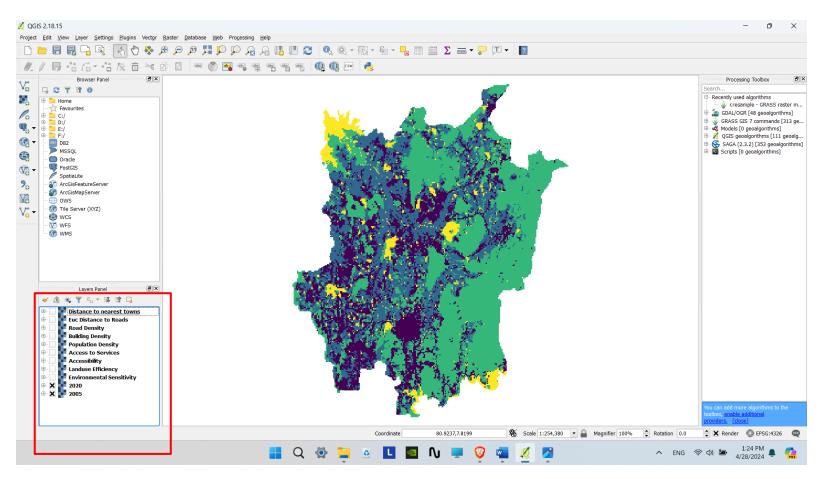


5. Click on the "**MOLUSCE**" and open the plugin now. The plugin will appear in the following way.

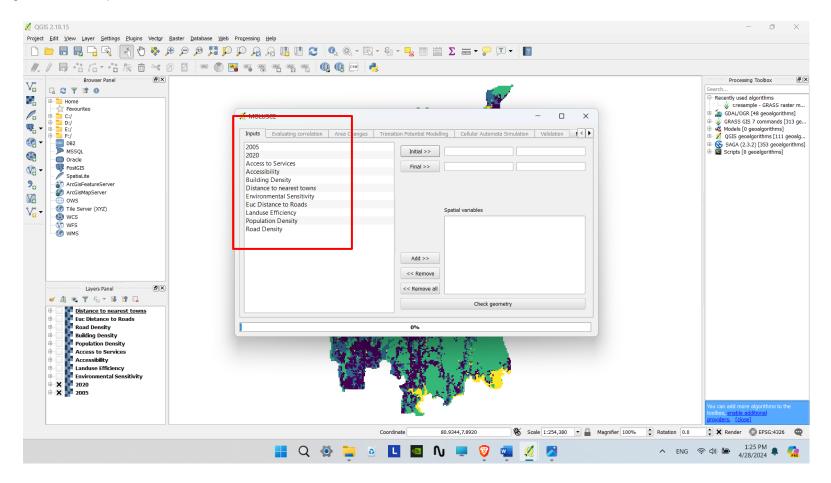


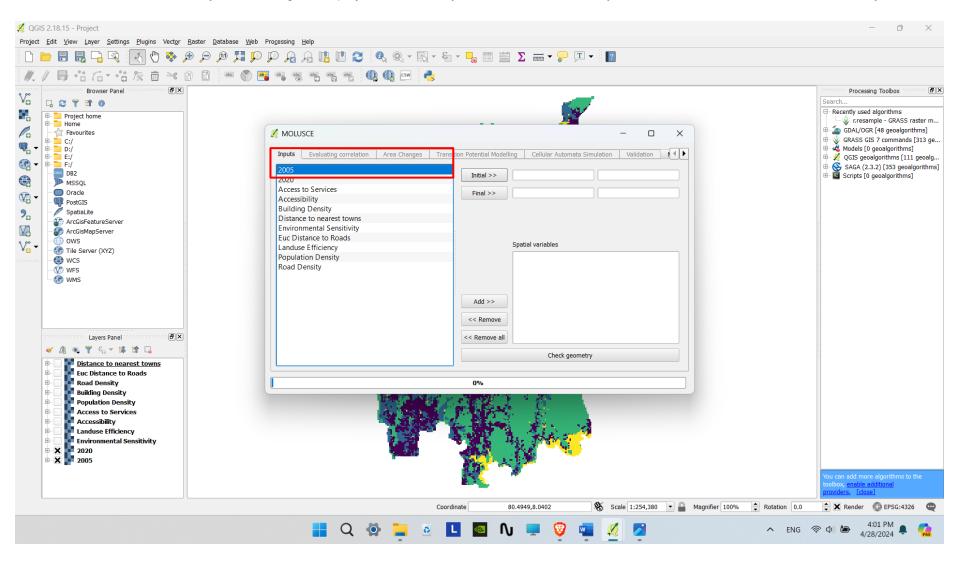
3.1 Modeling process with MOLUSCE

All the land use layers and layers for the spatial variables should be imported to the QGIS. Then, you can see that the **Layers Panel** contains all these layers. Next, we can proceed with the MOLUSCE plugin.



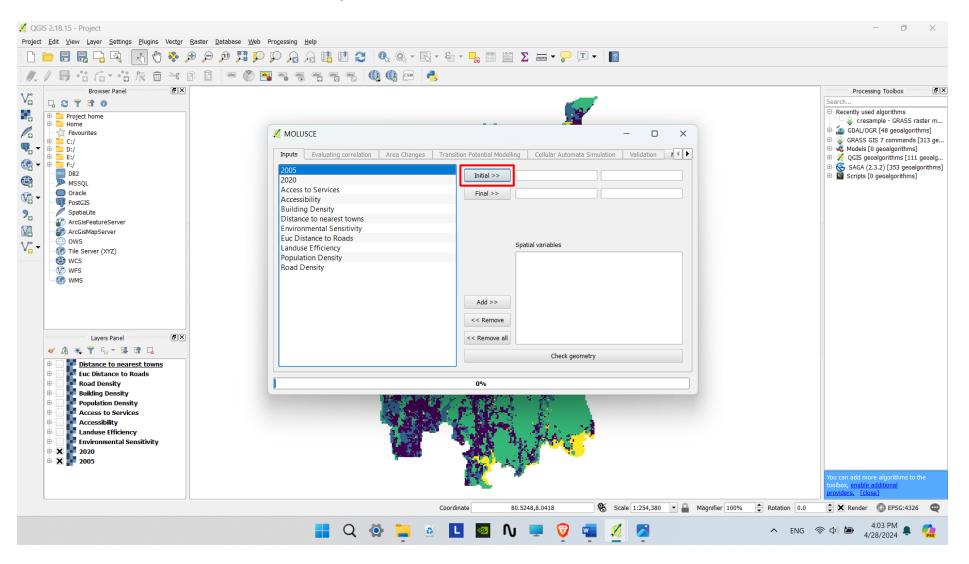
Open the MOLUSCE plugin from the Raster toolbar. You can see all the layers in the project are shown in the "**Inputs**" tab here. The next step is to insert layers into the model as required. This plugin is very easy to use, and for this, it is important to set up the layers we use correctly. To predict the future land use change, the land use layers of two years should be used. The historical land use layer as the **initial layer** and the current land use layer as the **final layer** should be given here as inputs.



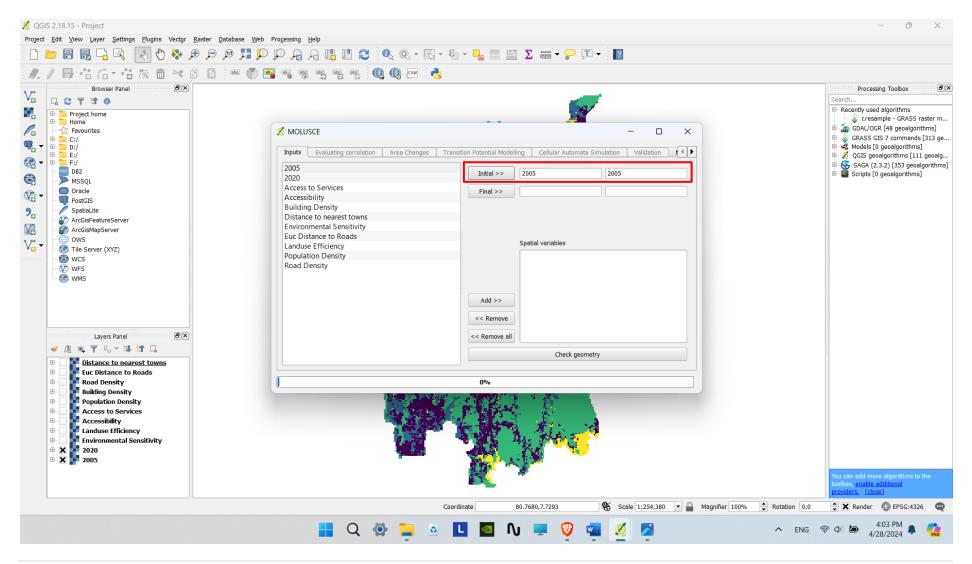


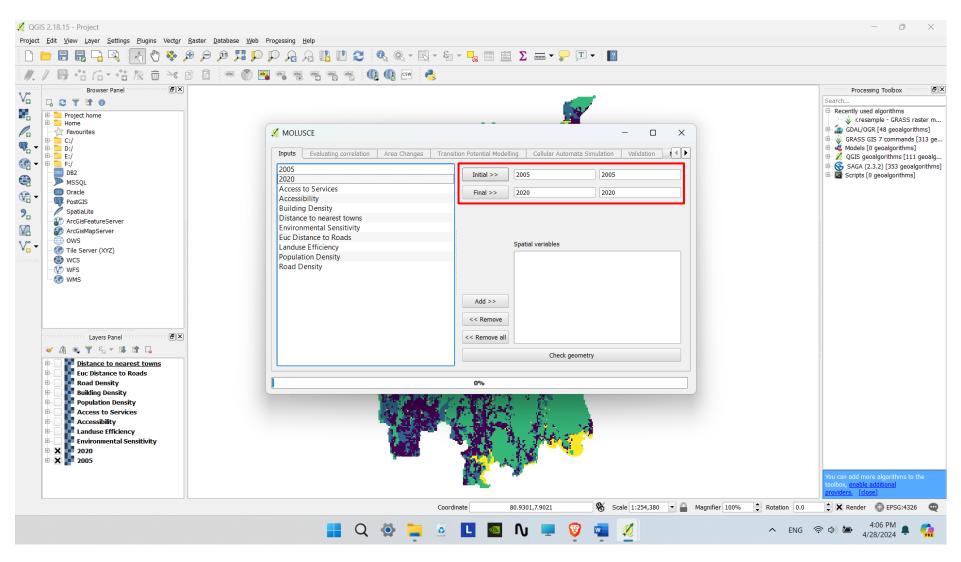
First, we have to add the initial layer. According to this project, the initial layer is the 2005 land use layer. Now click on "2005" to select the initial layer.

Then, click on the "Initial" button to add the selected layer to the model.



The initial layer was successfully added to the model. It is shown as follows.

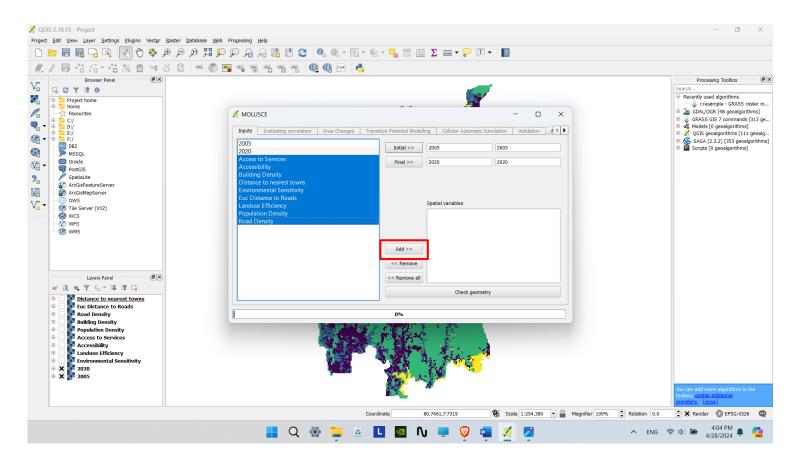




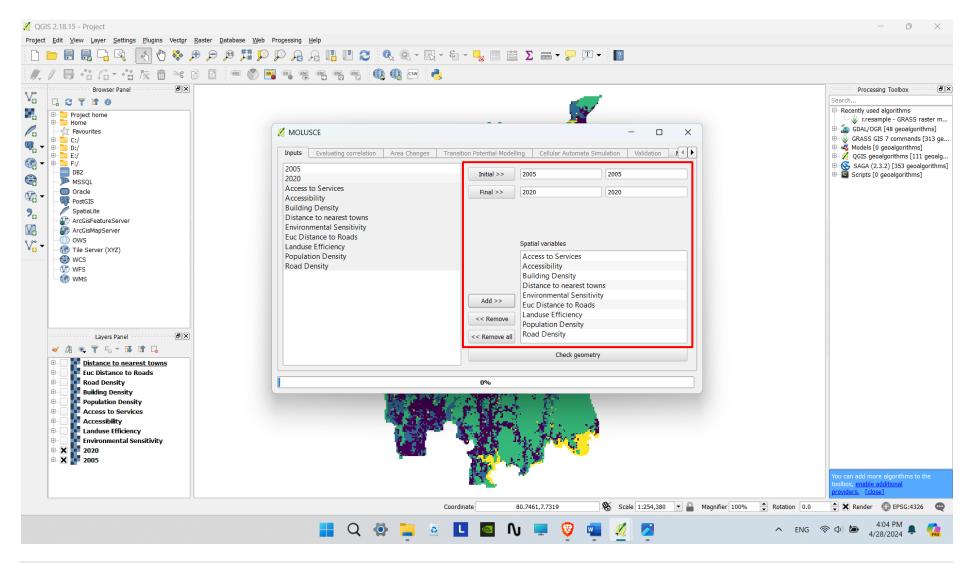
With the same steps, you can add the Final layer to the model. In this scenario, our final layer is the 2020 land use layer. Click on "2020" and proceed.

In the next step, you have to add the spatial variables to the model. Here we consider the factors that affected the land use change in the period we consider above. That is how the future land use change is predicted through this plugin. The layers related to those factors should be added here under **Spatial Variables**.

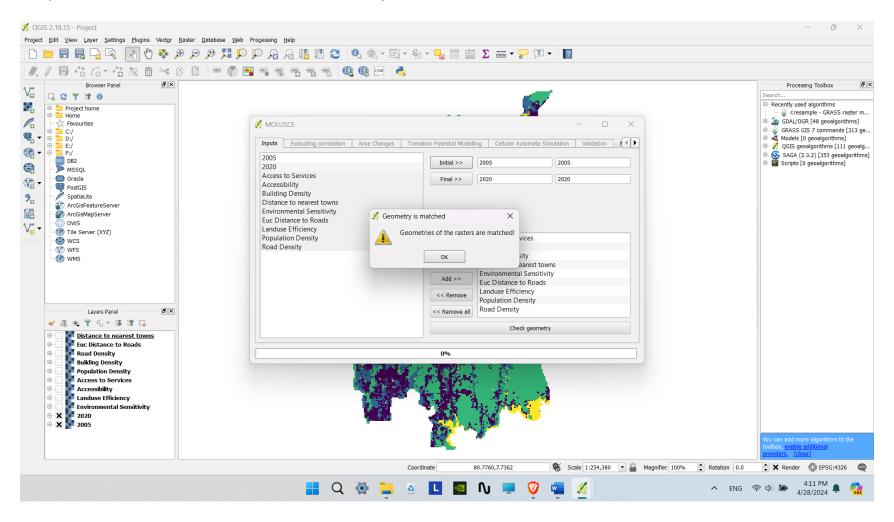
Following the same steps as before, you can add one by one layer to the model, or if you want to add these layers easily, select all spatial variables using the Ctrl key and click on "**Add**".



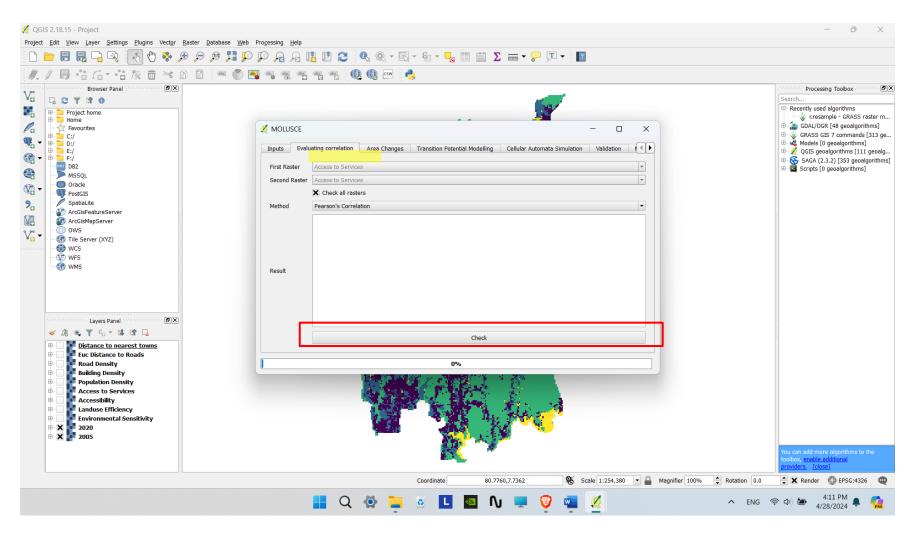
Now, all the layers are successfully added to the model.



Next, the geometries of the layers need to be checked. For that, click on "**Check geometry**". If the geometries of the all rasters are matched, the below message will be displayed. If the geometries of all the layers are not the same, the next step cannot be taken and an error message will be shown. Then the coordinate reference systems, rows and columns values, and cell sizes of all layers have to be rechecked.



Then, go to the "**Evaluation correlation**" tab. Here, Pearson's Correlation is used as the method. Now click on "**Check**" to proceed and you will get the matrix within a few seconds.



This matrix of correlation coefficients helps to understand how each spatial variable correlates with the actual changes in land use over time. By examining these correlations, we can identify which spatial factors have the strongest influence on land use dynamics and which may have a weaker or negligible impact.

This information is crucial for refining the predictive models within MOLUSCE, as it allows us to prioritize the inclusion of spatial variables based on their significance in driving land use changes. This helps to improve the accuracy and effectiveness of the predictive models by better aligning them with the real-world relationships between spatial variables and land use dynamics.

In the context of Pearson's correlation coefficient, a value of 1 indicates a perfect positive linear relationship between the two variables being compared. This means that as one variable increases, the other variable also increases proportionally. In the evaluation correlation tab of the MOLUSCE plugin, if a correlation coefficient is close to 1, it suggests a strong positive correlation between the spatial variable and the observed land use changes.

Values close to -1 or 1 indicate strong correlations, while values closer to 0 suggest weaker correlations. The sign of the correlation coefficient (+/-) indicates the direction of the relationship (positive or negative). Therefore, a correlation coefficient of 1 signifies a strong positive relationship, which is generally considered desirable in predictive modeling.

	Distance to nearest towns	Euc Distance to Roads	Building Density	Environmental Sensitivity	Accessibility	Road Density	Landuse Efficiency	Population Density	Access to Services
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Euc Distance to Roads			-0.367526722507	0.352616575335	-0.242689903437	-0.36763013485	-0.374035378235	-0.453683300652	0.465530602022
Building Density				-0.478106979998	0.529866692586	0.6872115136	0.62881778748	0.642996464628	-0.334377799996
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Accessibility						0.576923946527	0.513134186465	0.29596831616	-0.316026309295
Road Density							0.572695074381	0.417413174729	-0.36235275017
Landuse Efficiency								0.40414335433	-0.442368556311
Population Density									-0.27707102474
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When studying this matrix, we can see that the correlation between some variables takes negative values. That is, it can be recognized that those factors may have a weak or negligible effect on land use dynamics in the Dambulla area.

Next, go to the tab "Area Changes". Set the units as "sq. km." as follows. Then click on "Update tables".

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Then you will get this table and the matrix. The plugin calculates the area covered by each land use category in both time periods and then determines the changes that have occurred, such as expansion, contraction, or stability of each land use type. The purpose of this functionality is to provide us with quantitative insights into how land use has evolved or shifted over time within a specific region or area of interest. By quantifying the changes in land use, users can identify trends and patterns of land use dynamics. This information is invaluable for understanding and assessing the impacts of human activities or environmental factors, and informing land management and planning decisions.

The numbers 1, 2, 3, and 4 in the class statistics table and the transition matrix indicate the four land use categories that we have selected. In this class statistics table under the "Area Changes" tab, the area change can be 0. This would indicate that the particular land use class has not experienced any change in the area between the initial and final periods being analyzed. The transition matrix shows how much area has transitioned from one land use class to another between the initial and final time periods. Each cell in the matrix represents the amount of area that has changed from one specific class to another.

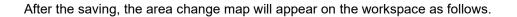
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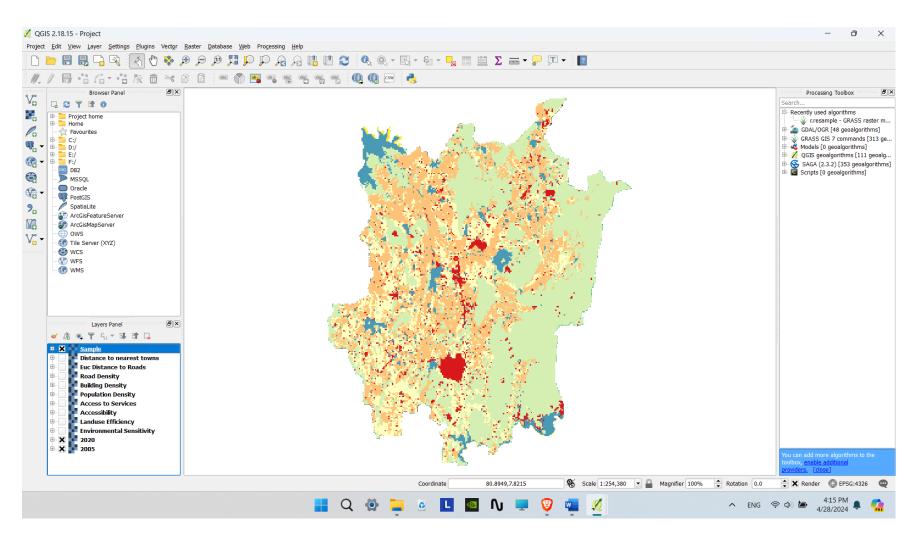
Additionally, the "Area Changes" tab allows us to visualize these changes through a map, enhancing the interpretation and communication of the results. For that, click on "Create changes map" and select a location to save the map as your preference.

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After clicking on "**Save**" in the previous step, the process will run as the below image.

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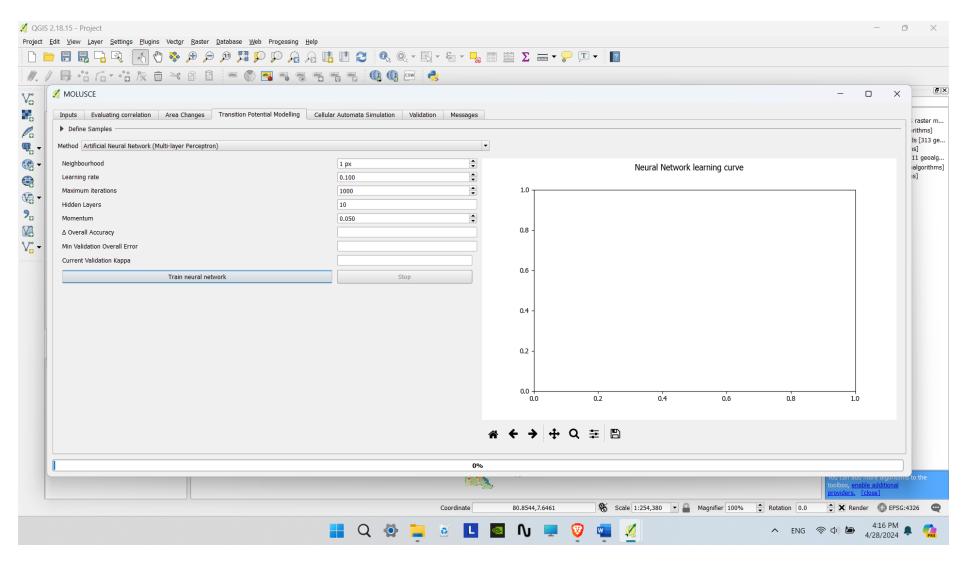




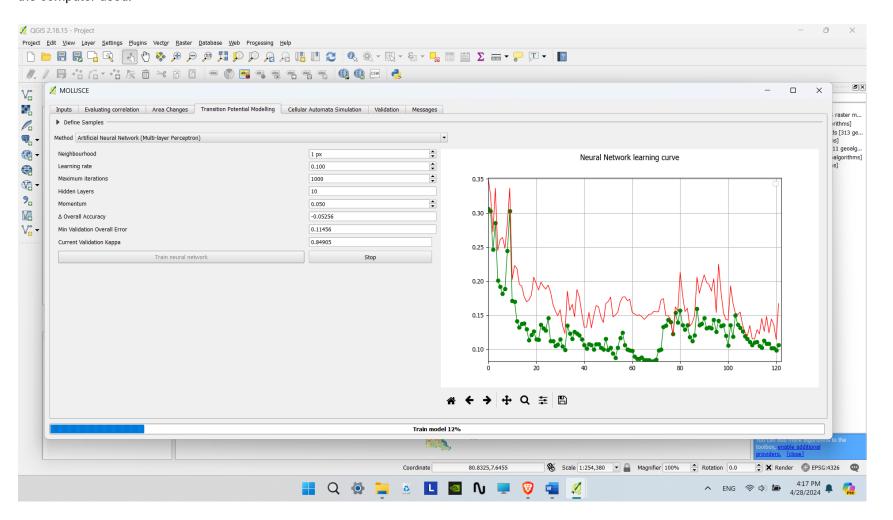
As the next step, go to the tab "Transition Potential Modeling" tab. Usually, we use here the Artificial Neural Network (Multi-layer Perceptron) as the method. Other parameters can be used as default values.

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Then, click on "**Train neural network**".

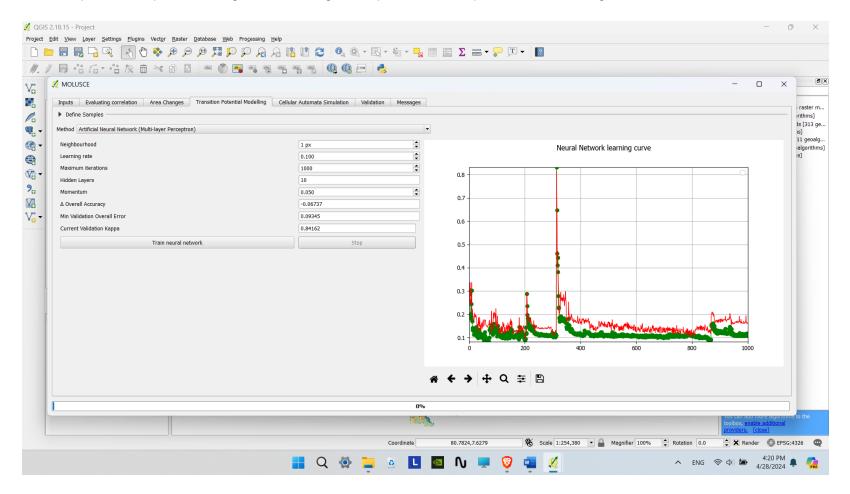


Now the model starts to train as follows. This will take a few minutes. This time depends on the speed of your internet connection and the processing speed of the computer used.



Under this part, utilizing the Artificial Neural Network (ANN), specifically the Multi-layer Perceptron (MLP) method, involves a structured process. Firstly, we selected spatial variables influencing land use change. Then, raster data representing these variables for past and present periods are inputted. The plugin

trains the MLP model using this data, calibrating it to estimate the likelihood of transitions between different land cover types. Subsequently, MOLUSCE generates transition potential maps, delineating areas with heightened probabilities of specific land use changes.



The **neural network learning curve** represents the performance of an artificial neural network (ANN) during training. It typically shows the training loss (also known as the error or cost) on the **y-axis** and the number of training iterations or epochs on the **x-axis**. The training loss measures how well the ANN is fitting the training data, and observing this curve helps determine if the model is overfitting or underfitting. As the number of iterations increases, the training loss

ideally decreases, indicating improved model performance. Keep in mind that specific implementations may vary, but this general trend holds for most neural network training processes.

The validation of kappa involves assessing the accuracy and reliability of the predictive models generated by comparing the predicted land use changes with observed changes here. Kappa statistics measure the agreement between the predicted and observed land use transitions, providing a quantitative measure of model performance. Higher kappa values indicate better agreement between the predicted and observed land use changes, implying greater accuracy and reliability of the predictive models.

"Delta overall accuracy" refers to the change in overall accuracy between two time periods. Overall accuracy is a measure of how accurately a predictive model or classification algorithm classifies land use categories compared to ground truth data. It represents the proportion of correctly classified pixels or areas out of the total number of pixels or areas.

The "delta overall accuracy" specifically measures the difference in overall accuracy between two time periods, typically past and present. This metric provides insights into how the accuracy of land use change predictions has changed over time. A positive delta in overall accuracy indicates an improvement in accuracy, suggesting that the predictive model is better at capturing land use changes in the present period compared to the past. Conversely, a negative delta in overall accuracy indicates a decrease in accuracy, implying that the model's predictive performance has deteriorated over time.

Then, go to the tab "Cellular Automata Simulation" tab. In this step, we have to browse a suitable location to save the simulation results.

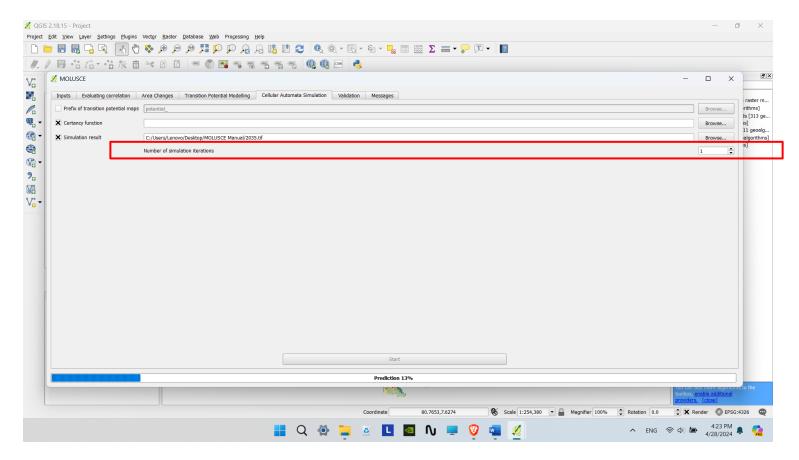
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Click on "Browse" and select a location as follows. Then, click on "Save".

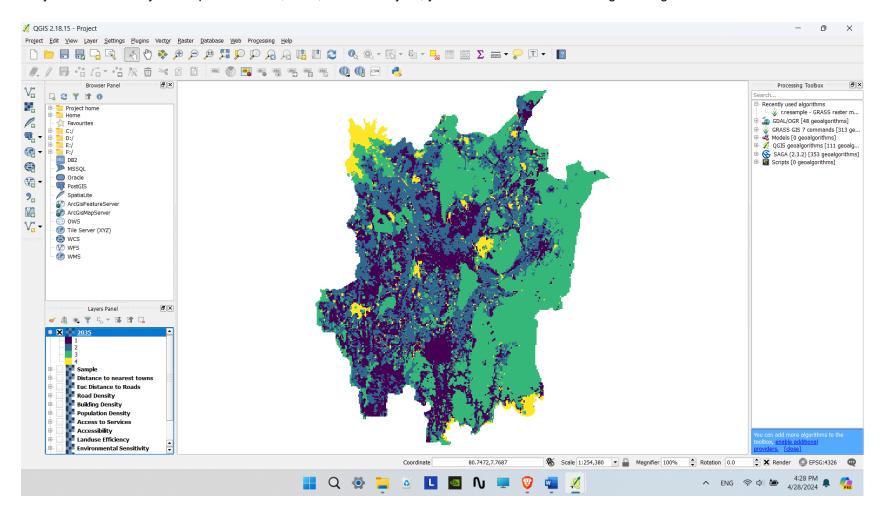
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Then we have to set the number of simulation iterations. We used here the land use layers for the years 2005 and 2020. The gap is 15 years. So, one iteration equals 15 years here. If we set the number of iterations as "1" here, the prediction will be given for the year 2035. If it is set as "2", the prediction will be given for the year 2050.

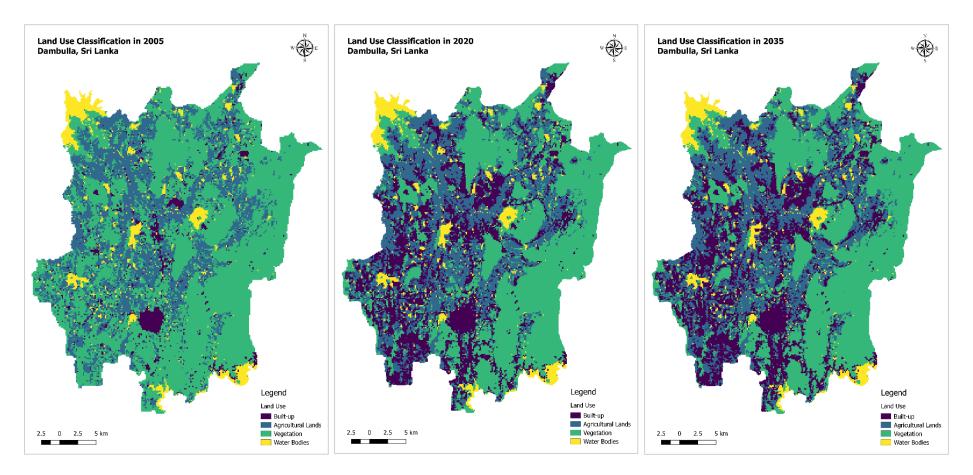
After setting up the number of iterations as above, click on "Start". Then the prediction will be started and it will be saved in the location that you selected before.



Once the prediction is done, that layer will appear on the workspace as follows. In this scenario, the number of iterations was set as "1", so this prediction is for the year **2035**. When you compare the 2005, 2020, and 2035 layers, you can see the land use change among those.



3.2 Past, present, and future scenarios of land use in the Dambulla region

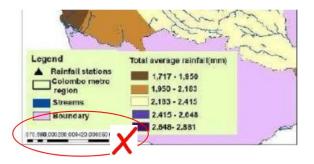


4.PREPARATION OF MAPS

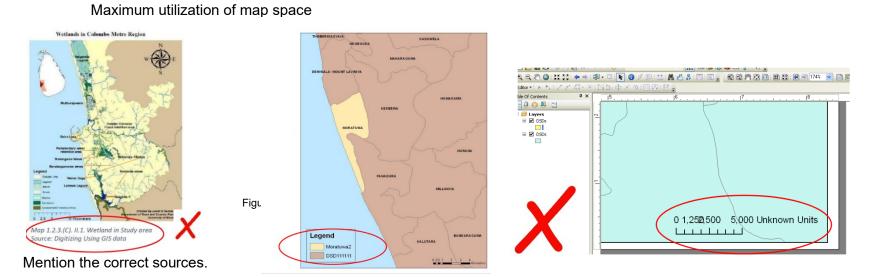
- 1. Use Suitable Colors & Symbols
- 2. Show adjacent administration boundaries.
- 3. Maximum utilization of map space
- 4. Show the Graticule Network with appropriate grid size.
- 5. Show the basic elements in the map.
 - a. Transportation Networks
 - b. Water Bodies
- 6. Prepare a descriptive map.
 - a. Label notable features.
 - i. Major Road Types
 - ii. Major Rivers
 - iii. GN Boundaries
 - iv. If needed, show the location of the area in a different data frame.
- 7. Check the units of the scale bar.
- 8. Mention correct units at the legend.
- 9. Check the text given in the legend.
- 10. Mention the correct sources.

Examples





Check the units of the scale bar.



AFTERWORD

Effective land use planning requires more than just understanding current conditions—it demands foresight, analytical precision, and the ability to simulate change. This textbook provides a rigorous, methodologically sound framework for modeling future land use scenarios using the MOLUSCE plugin in QGIS, grounded in robust algorithms such as Artificial Neural Networks, Logistic Regression, and Weight of Evidence.

Developed with both academic and professional audiences in mind, this book bridges theory and application, enabling users to engage confidently with complex spatial dynamics. As the pressures of urbanization, environmental change, and resource management intensify, tools like these become indispensable for anticipating growth, mitigating risks, and guiding sustainable development.

We hope that this publication not only enhances technical proficiency but also fosters critical thinking and strategic planning in support of resilient, adaptive landscapes. May it serve as a lasting resource for those committed to shaping the future of land use through data-driven insight and informed decision-making







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