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Climate Responsive Land Governance and Disaster Resilience: Safeguarding Land Rights

Improving Cadastral Accuracy for Disaster Management: The Role of Segment Anything Model (SAM) in Digitizing Historical Cadastral Maps

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Contents

- Introduction to cadastral challenges in Nepal and approaches in automatic digitization
- Study Focus and Objectives
- Materials and Methods
- Results and Analysis
- Conclusion and Recommendations

Natural Disaster and Impacts on Land Administration

Thame Before Flood

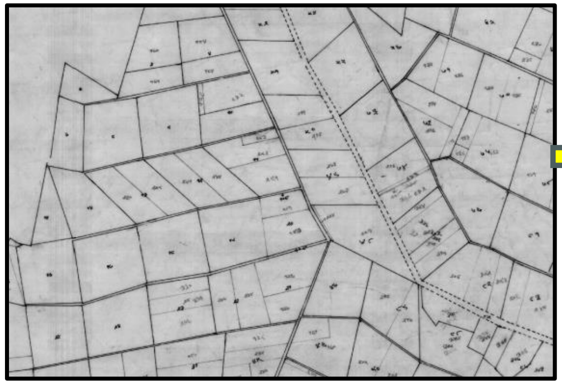
Dump of Damaged Land Records

chowk Landslide

Source: NDRRMA, Nepal

Cadastral record digitization and its challenges

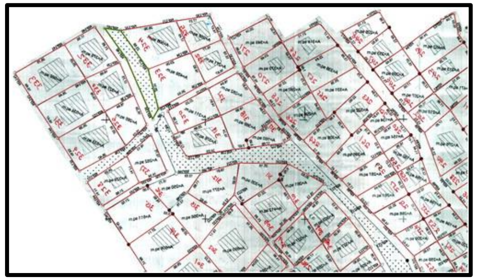
Department of Land Information and Archive (DoLIA)



Scanned Analog Cadastral Map

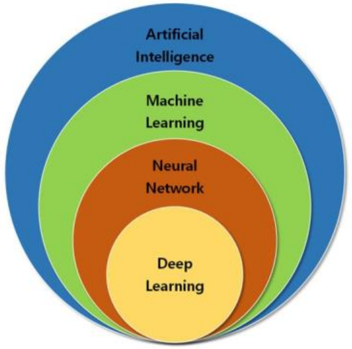
Digitized Cadastral Map

Automatic extraction of cadastral records



Skeletonizing

Segmentation

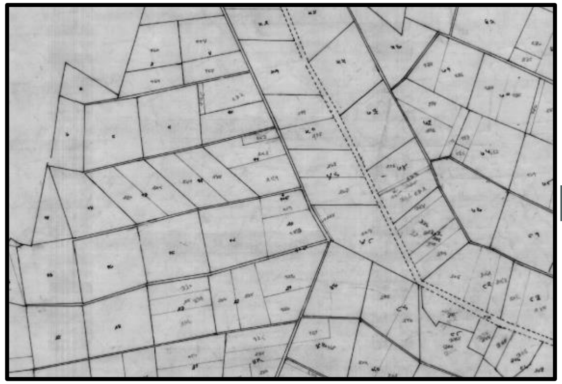


Semantic Segmentation

Segment Anything Model (SAM)

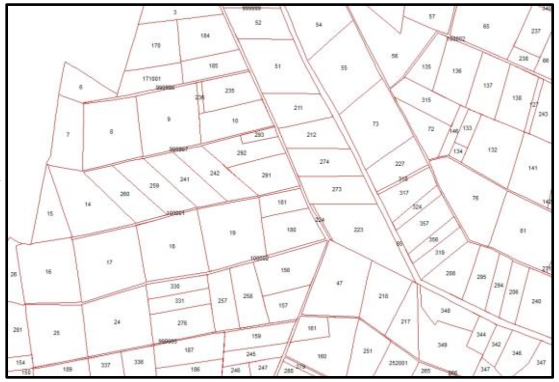
- Released by Meta AI research - zero-shot learning
- Can adapt to new datasets and perform unfamiliar tasks using '**prompting**' techniques, even with little or nor prior training

Objectives



Scanned Cadastral Image

Zero-shot



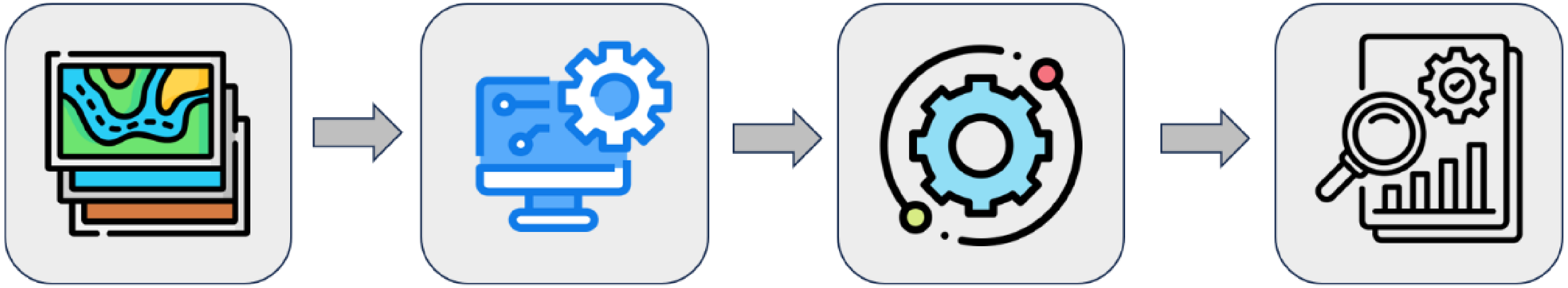
Cadastral Database

Feasibility

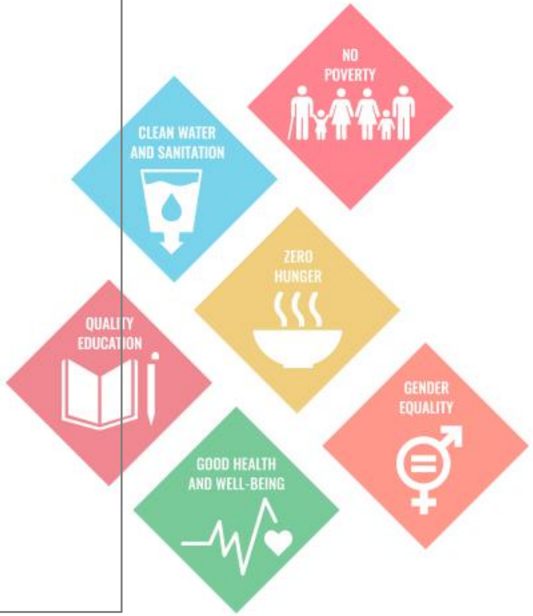
Effectiveness

Materials and Methods

Cadastral Data Synthesis	Prompt Configuration	Zero-Shot	Evaluation



Cadastral Data Synthesis	Prompt Configuration	Zero-Shot	Evaluation
Different sized Different shaped Different visibility & noise Different scanning resolution	Single & multi-point Bounding box Combination	Model adaption Segmentation	Data Comparison



Cadastral Data Synthesis

Cadastral Data Synthesis

Key five attributes:

Shape/Parcel Density

Parcel Size and Eccentricity

Parcel Boundary Visibility

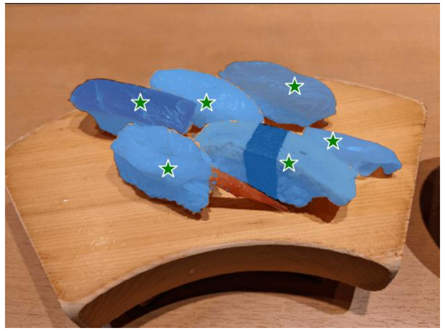
Noise condition

Scanning resolution

Prompt Configuration

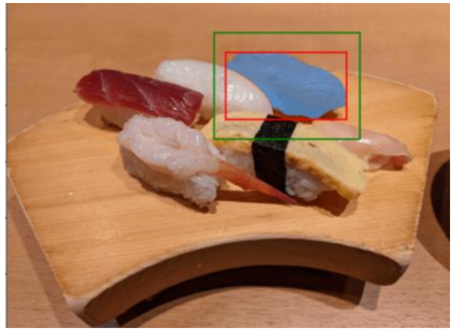
Prompt Configuration

Zero-Shot Learning



Multi-Point

Combination

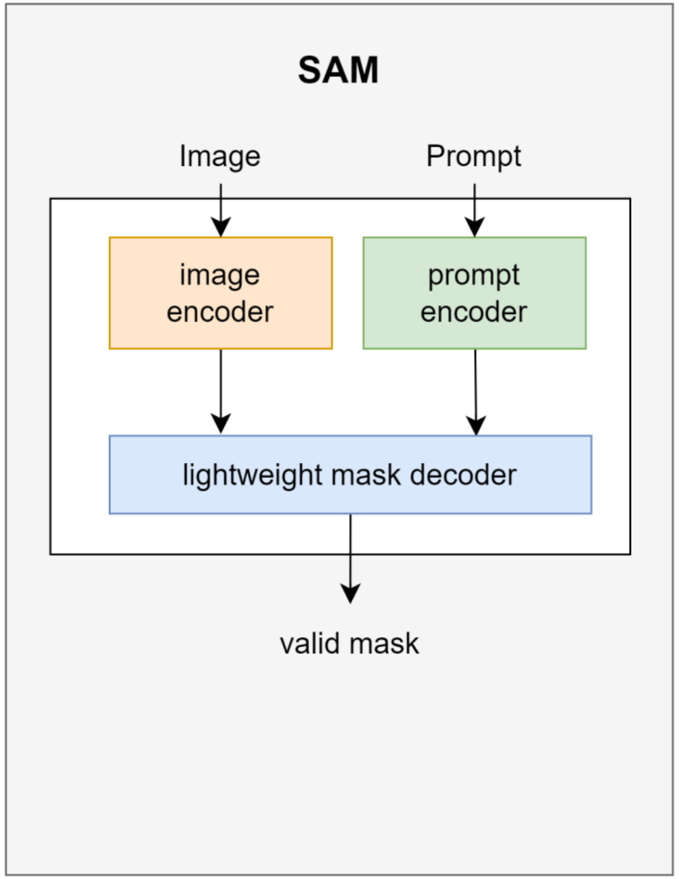


Bounding Box

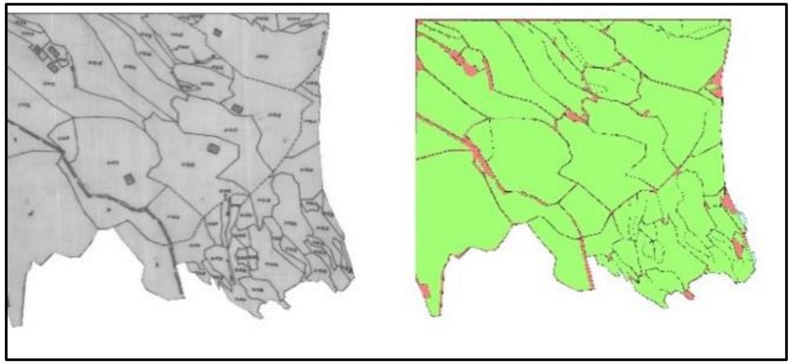
Zero-Shot


Zero-Shot

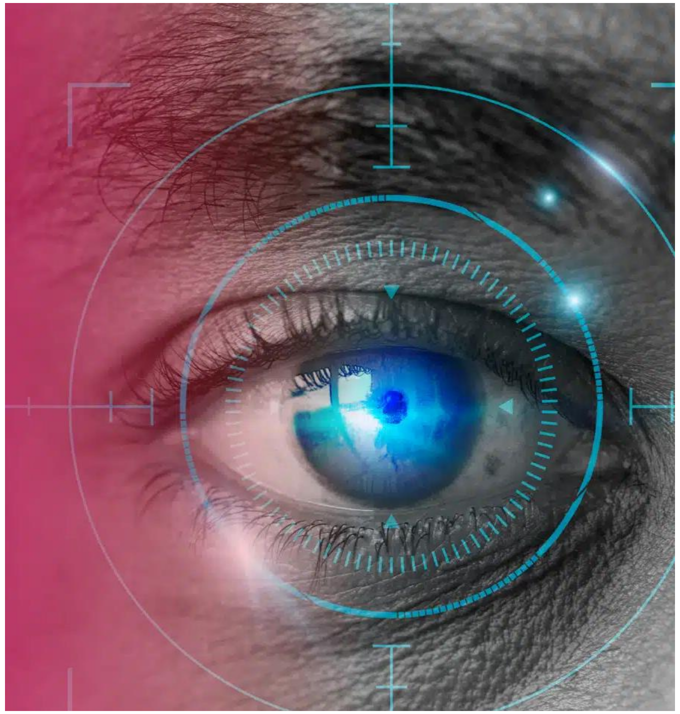

GEOSAM


SAM
Image
Prompt
image encoder
prompt encoder
lightweight mask decoder
valid mask

Model Evaluation



Visual Inspection



Result and Analysis: Parcel Density

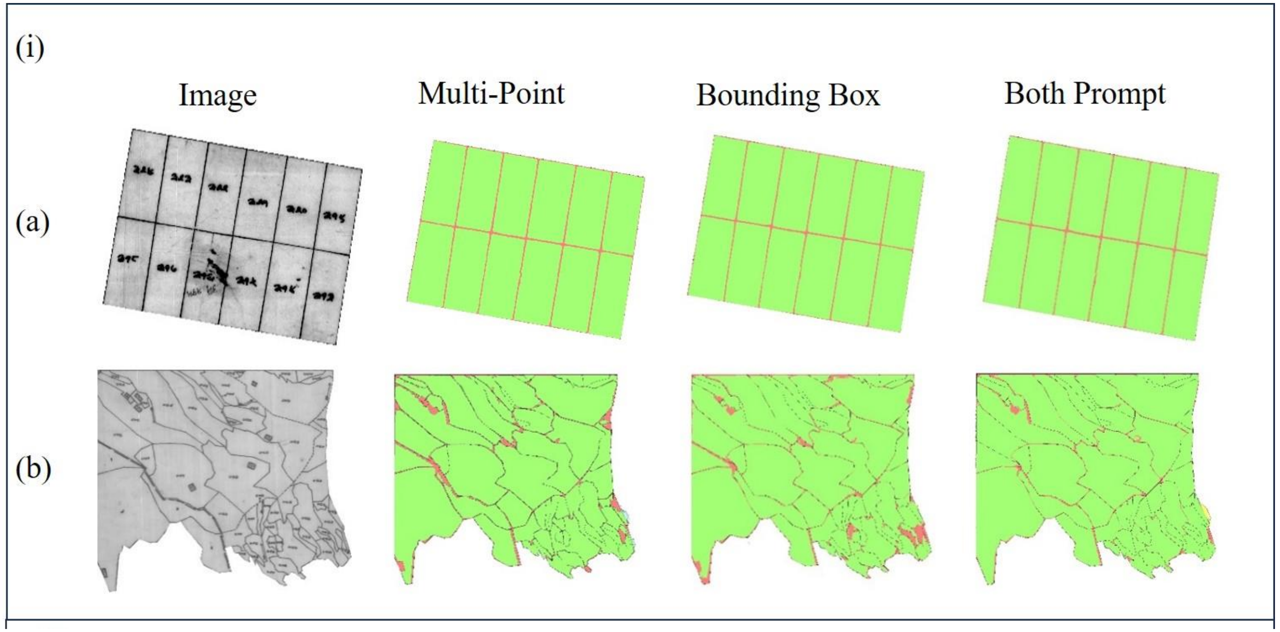


Figure : Visualization of prediction of three variations of prompts of zero-shot segmentation of SAM on cadastral parcel extraction task from historical scanned cadastral images (i) based on parcel density (a) equally sized; (b) dense and variety of pixel

Equal Size – High accuracy

Dense and Variety of Parcels – noticeable decline in accuracy

Underestimation mitigated by employing the combination

Proximity of adjacent parcel – **boundary confusion and misclassification**

Limited resolution – difficulty in capturing finer details

Result and Analysis: Parcel Size and Eccentricity

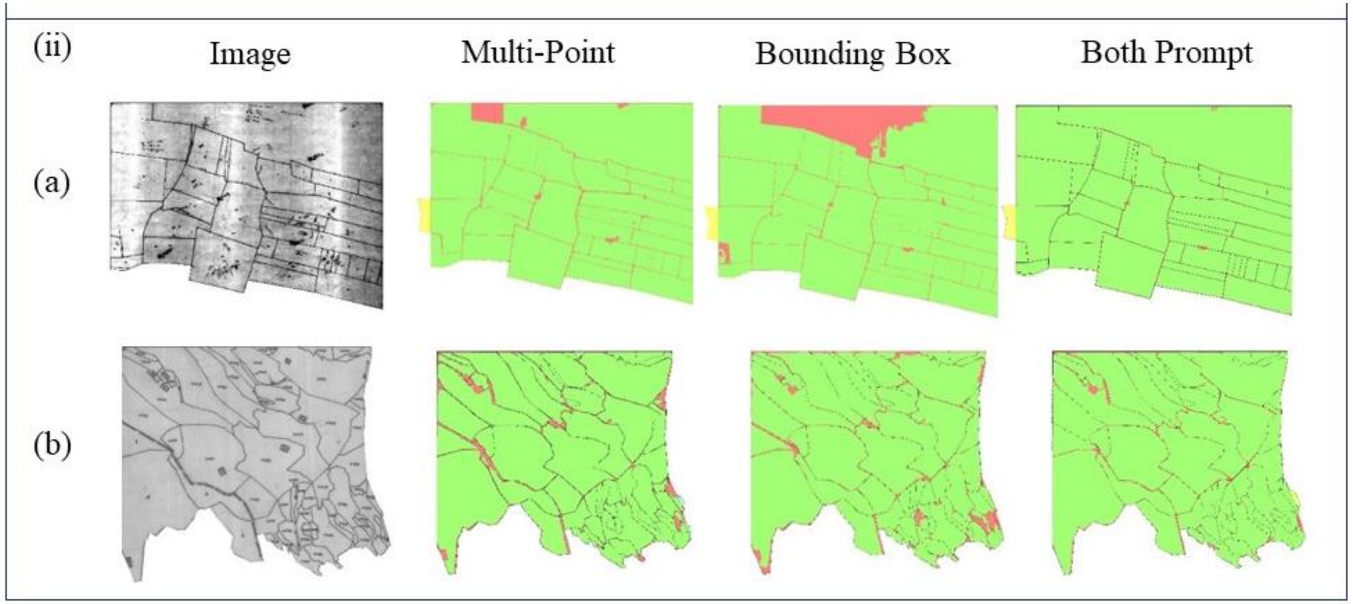


Figure : Visualization of prediction of three variations of prompts of zero-shot segmentation of SAM on cadastral parcel extraction task from historical scanned cadastral images (ii) based on combination of parcel size and its eccentricity.

All sized parcel – accurately extracted – matched well defined **geometric shape** (eccentricity close to one)

Underestimation – delineating larger parcels with **high eccentricity**

Segmentation accuracy- highly **correlated** with their **eccentricity** – **heterogeneity** within the parcel

Result and Analysis: Visibility

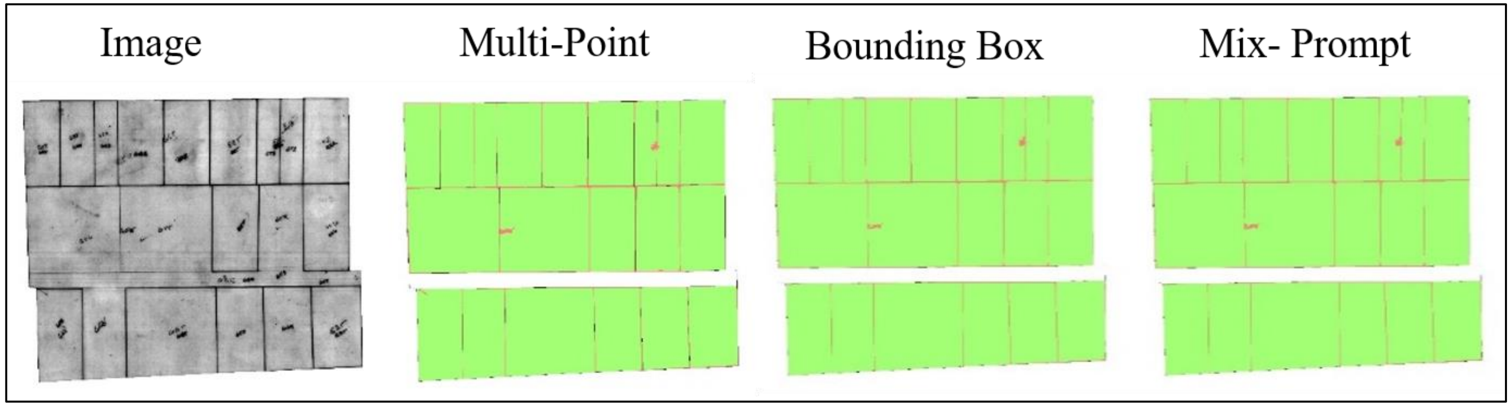


Figure : Visualization of prediction of three variations of prompts of zero-shot segmentation of SAM on cadastral parcel extraction task from historical scanned cadastral images (i) based on parcel visibility

All prompt produced **promising** results in delineating parcels, even under **varying degrees of boundary clarity or ambiguity**

Result and Analysis: Noise

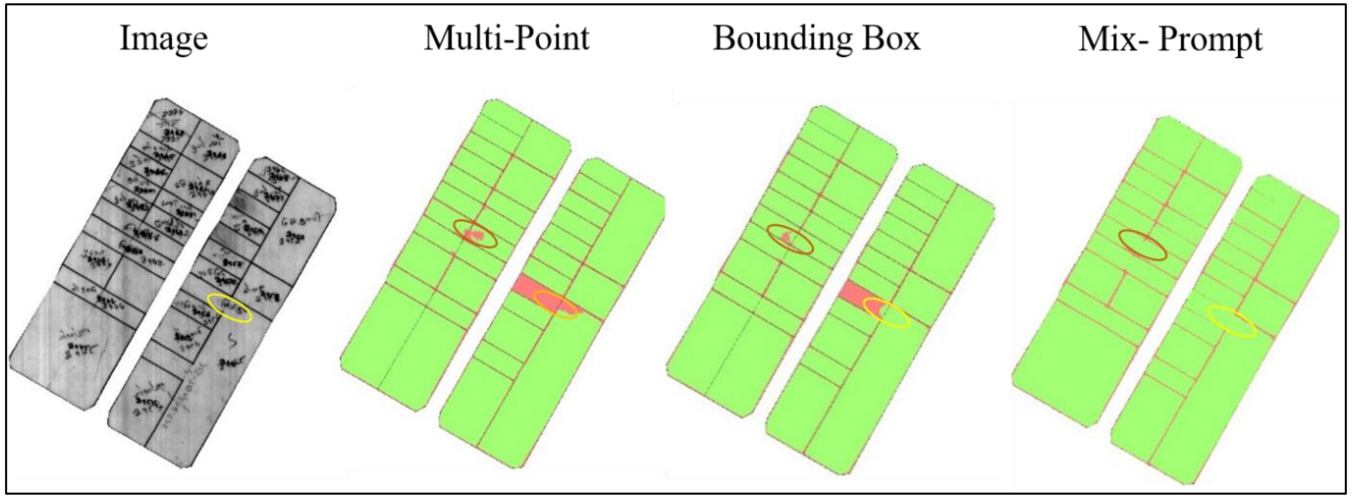


Figure : Visualization of prediction of three variations of prompts of zero-shot segmentation of SAM on cadastral parcel extraction task from historical scanned cadastral images (i) Noise level

Noise within boundary – didn’t impact performance

Noise adjacent to boundaries – significantly decrease accuracy

Model either failed to delineate parcel or mistakenly merged two adjacent parcels into one.

Result and Analysis: DPI

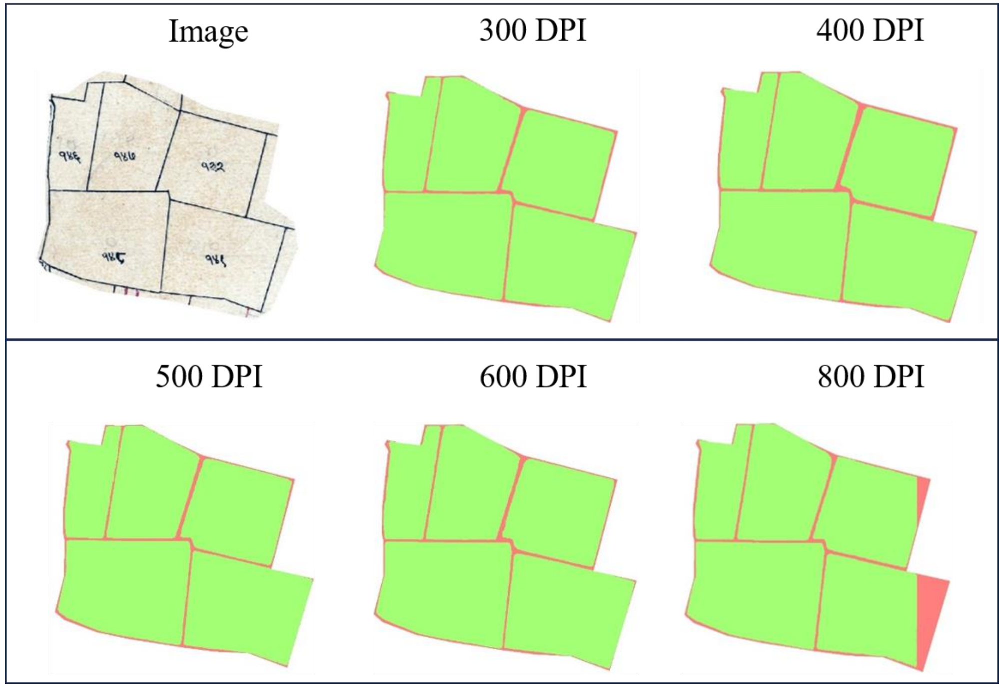


Figure : Visualization of prediction of three variations of prompts of zero-shot segmentation of SAM on cadastral parcel extraction task from historical scanned cadastral images (i) Different DPI

Increasing the scanning resolution – didn’t increase accuracy

Delineation capability further decreased with higher scanning accuracy

Reduction in performance – increased heterogeneity in higher resolutions

Conclusions

- Conducted comprehensive analysis of the **zero shot segmentation** capabilities of SAM for cadastral data extraction from **scanned historical cadastral maps** under various **scenarios and complexities**
- **Combination of base prompts** consistently outperforms individual base prompts in the zero shot learning approach across all datasets.
- demonstrated the potential to significantly reduce human workload and error with minimal or no supervision

Challenges/Limitations

- Faces challenges when **handling noisy** data near boundaries and areas with **complex parcel configurations**
- Occurrence of **false positives** between segmented parcels remains a **persistent issue**.
- **initial experiment** was **limited** to exploring SAM's **zero-shot capabilities**
- These challenges highlights the need for **GIS with SAM, along with human oversight**, to ensure the creation of accurate and complete cadastral databases

Recommendations

- On evaluating SAM's **one-shot segmentation** capabilities as well as **SAM-2 model**
- potential to integrate with diverse **remote sensing data**, and integrate with cadastral map
- well-suited for Nepal's varied geographic conditions, especially in **post-disaster scenarios** like earthquakes or floods.
- By incorporating **SAM** into existing **GIS platforms and remote sensing workflows**, Nepal's **cadastral system** can be made **more resilient** to natural disasters and ongoing land use challenges

Thank you

Welcoming You For
Any Questions!!!