INDONESIA INFRASTRUCTURE INITIATIVE

Socio-ecological tools in the development of mineral infrastructure

SMEC
Local People. Global Experience.

Australian Government
Department of Foreign Affairs and Trade

Australian Aid

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AIIRA RESEARCH REPORT

Revised 27 November 2015

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Brisbane and Bandung

27 November 2015

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ACRONYMS

AIIRA	Australia Indonesia Infrastructure Research Awards
AMDAL	*Analisa Mengenai Dampak Lingkungan* or Environmental Impact Analysis
BAPPEDA	*Badan Perencanaan Pembangunan Daerah* or Regional Development Planning Office
BAPPENAS	*Kementerian Perencanaan Pembangunan/Badan Perencanaan Pembangunan Nasional* or Ministry of National Development Planning/National Development Planning Agency
BKPM	*Badan Koordinasi Penanaman Modal* or Investment Coordinating Board
BKPRD	*Badan Koordinasi Penataan Ruang Daerah* or Regional Coordinating Board for Spatial Planning
BKPRN	*Badan Koordinasi Penataan Ruang Nasional* or National Coordinating Board for Spatial Planning
BPN	*Badan Pertanahan Negara* or National Land Agency
BULOG	*Badan Urusan Logistik* or the Bureau of Logistics
CoW	Contract of Work
CSR	Corporate Social Responsibility
CSRM	Centre for Social Responsibility in Mining
DFAT	Department of Foreign Affairs and Trade
GIS	Geographic Information System
GoI	Government of Indonesia
ICMM	International Council on Mining and Metals
IM4DC	International Mining for Development Centre

IndII	Indonesia Infrastructure Initiative
ITB	*Institut Teknologi Bandung* or Bandung Institute of Technology
IUP	*Ijin Usaha Pertambangan* or Mining Business License
KKPPI	*Komite Kebijakan Percepatan Penyediaan Infrastruktur* or Policy Committee for the Acceleration of Infrastructure Provision
PT KPC	PT Kaltim Prima Coal
MCA	Multi Criteria Analysis
MP3EI	*Master Plan Percepatan dan Perluasan Pembangunan Ekonomi Indonesia* or the Master Plan for Acceleration and Expansion on Indonesia's Economic Development
Musrenbang	*Musyawarah Perencanaan Pembangunan* or the Annual Development Planning Process
PPP	Public Private Partnership
RG-RCIS	Research Group for Regional and City Infrastructure System
SOE	State-Owned Enterprises
UQ	University of Queensland

EXECUTIVE SUMMARY

BACKGROUND / INTRODUCTION

The infrastructure required by mining operations can provide opportunities for developing countries like Indonesia to leverage their mining investment for broader development objectives. However, such infrastructure needs to negotiate social and environmental concerns. Effective planning tools that incorporate spatial technology and social engagement can assist in the design of infrastructure corridors that are sensitive to socio-ecological factors and enable the active participation of impacted communities. In this research project we hypothesise that mining projects that use these tools have greater potential to meet development objectives with minimal conflict, while making it more likely projects will obtain community acceptance. The main goal of this research is to answer two main research questions:

1. What are the key factors that need to be included when planning sustainable infrastructure development associated with mining industries?

2. How can these factors be incorporated into a tool that can be used to better plan infrastructure development associated with mining operations in resource-rich regions of Indonesia?

In answering these research questions, we utilised two case studies of infrastructure corridor development: one in East Kutai Regency in East Kalimantan Province; the other in South Konawe Regency in South East Sulawesi Province. The research had the following objectives:

a) Benchmark key socio-ecological factors for mineral infrastructure planning

b) Evaluate current mineral infrastructure development and investigate its socio-ecological impacts

c) Develop an optimisation model using least-cost path analysis as a GIS modelling tool for future infrastructure corridor planning

d) Recommend a framework for community engagement in mineral infrastructure planning in Indonesia

We expect that the research findings can inform the development of mineral infrastructure policies in Indonesia. The GIS tools in this collaborative research can provide a platform for further research in this field and better scientific engagement in Indonesia's infrastructure planning.

MINERAL INFRASTRUCTURE AND PLANNING ISSUES

Through our background and scoping research on mineral and infrastructure planning issues in Indonesia we made the following key findings in the initial phase of the project:

- Three categories of mineral infrastructure should be considered: i) infrastructure to support the mine operation and its supply chains; ii) community infrastructure as part of a company's corporate social responsibility (CSR); and iii) regional infrastructure to stimulate growth. We observed these three categories of infrastructure in both case study regions and found that large scale mining has more diverse and better standards of mineral infrastructure in comparison to the medium/small scale mine operations.

- Mineral infrastructure planning in Indonesia is not specifically defined – subsequently, it cannot be separated from infrastructure and regional planning systems in Indonesia. There are multiple agencies and regulatory requirements involved in these. Key respondents suggested that coordination among different sectors and levels of government has been a challenge.

- Lack of both horizontal and vertical coordination was raised as a problem in discussions about the development of mineral infrastructure, in particular for port development. National, provincial and regency governments all noted issues associated with implementing planning mechanisms in practice. Many of the government respondents interviewed commented that while planning mechanisms (e.g. Spatial Plans) are developed and "look good on paper", there are often issues surrounding the implementation of such plans. Others suggested that land allocations and permits for developments are influenced by political agendas and vested interests which sometimes caused difficulties in implementing the spatial plan. When asked for examples, respondents were hesitant to provide details.

- Interviews with key respondents indicated that socio-ecological factors are often not considered in mineral infrastructure planning. Most participants had difficulties in describing the types of socio-ecological factors that may be considered. However, some participants gave general feedback in relation to the socio-ecological factors considered in the development of spatial planning and Environmental Impact Assessment (AMDAL) processes. We conclude that key respondents' understanding of environmental factors is well understood in comparison to social factors.

SOCIO-ECOLOGICAL FACTORS FOR MINERAL INFRASTRUCTURE PLANNING

From a literature review, an initial list of six broad socio-ecological factor categories was identified, as well as their key elements. To refine these initial factors, the research team conducted 37 interviews/social surveys across multiple stakeholder groups (National Government, Provincial Government, Regency Government, community representatives and companies) to determine the perceived importance of each sub-factor. The questionnaire (Annexe 3) included a Likert scale from 1 to 5[1] for each sub-factor and participants were asked to rate each based on their perceived degree of importance. The mean rating value was calculated for each sub-factor to determine the average response across all stakeholder groups. To determine each sub-factor's cost weighting for the GIS Sustainability Maps, each sub-factor's value was rescaled and weighted.

Analysis from all socio-ecological sub-factors across all stakeholder groups (Figure 3.1) found that the most important sub-factors were population settlements and existing water bodies. However, all mean responses were Neutral (3) or higher. Respondents rarely attributed any of the sub-factors as not important (e.g. "Extremely not important" (1) or "Not important" (2)) with only 40 negative responses out of the 893 total individual responses for all sub-factors.

GIS EVALUATION OF COMPATIBILITY OF MINING AND ROAD INFRASTRUCTURE WITH SOCIO-ECOLOGICAL FACTORS

In this project, the research team applied GIS overlay analysis to evaluate the suitability of existing mining and road infrastructure with socio-ecological factors in the minerals rich East Kutai Regency case study area. Through interviews with the representatives of government and companies in East Kutai, we found that respondents believed there was a lack of a structured method for infrastructure planning; rather, there was a perception that infrastructure was built in an ad-hoc and reactionary manner without the use of well-defined methodology capable of taking into account the interactions of the social and ecological systems. Subsequently, we evaluated these current practices by analysing the compatibility between road infrastructure and socio-ecological factors. In this exercise, we performed GIS overlay and buffer analysis to existing road networks at three road hierarchies (national, provincial and local roads).

We found that the definition of mineral infrastructure is problematic in East Kutai Regency as the region was first known as a mining town. In this case, infrastructure was specifically built to serve mining activities. As the town developed and opened up for new settlements and other economic activities, we observed that current mineral infrastructure also served public and other economic activities. In our analysis, we tried to be consistent in analysing national, provincial and local roads. However, due to limited data availability, we did not analyse down to the level of local roads.

We investigated the geographic proximity of the existing road networks to selected social and ecological factors (e.g. community forests) in order to determine the extent to which such factors are considered in current infrastructure planning. A full

[1] 1 = "Extremely not important"; 2 = "Not important" 3 = "Neutral"; 4 = "Important"; and 5 = "Extremely important".

presentation of this analysis is provided in Annexe 4. The key findings of our analysis are as follows:

- There are two important conclusions relating to community factors (settlement, community agricultural land): First, national and provincial road networks do not provide adequate access for the population and do not adequately connect community settlements. This is supported by the fact that there is a low percentage of community land within the established buffer area. Second, the development of mineral infrastructure is within the appropriate locations of company mining leases. Subsequently, the road networks are located far from the community which can prevent conflicts between community and mining company.
- The development of mineral infrastructure nearby community forestry areas, water habitat, conversion area, and plantation area can be a driver of land use conversion. Large-mining companies should be cautious about the existence of conservation areas.
- The low percentages of water habitat and conservation area within 1km, 5km buffers for national and provincial roads show that the development of mineral infrastructure has largely respected conservation areas. Additionally, very small percentages of provincial road's buffers confirm the argument that few areas have been covered by road infrastructure.
- In developing mineral infrastructure, government and mining companies can work in partnership to provide regional infrastructure and work collaboratively for road maintenance. Key respondents in East Kutai Regency mentioned that a large-mining company has contributed to building regional roads under its CSR program and transferred these as national roads. The roads are a shared-use for public and industrial purposes (e.g. other mining operations in the region). However, current intensive uses from multiple mining activities have created tensions among users, in particular over maintaining the quality of the roads. Meanwhile, the responsible government has limited financial capacity for these roads' maintenance. In addition, co-sharing and multiple-use of roads should come with a careful consideration of different motives, roles and responsibilities of each party to promote long term mutual benefits. In this case, the advocacy and policy for mineral infrastructure development should be established in advance and among related stakeholders, including small-scale mining companies, who also use the mineral infrastructure.
- Land use conversion is one of the potential impacts that can result from the construction of mineral infrastructure. Strict policy about this conversion needs to be implemented not only for mineral infrastructure development but also for community settlement. During our fieldwork in East Kutai Regency in October 2014, we observed the emergence of new settlements within the proximity of newly built roads that are adjacent with conservation areas.
- We did the GIS analysis based on readily-available spatial data, especially to select socio-ecological factors for this analysis. In our literature review and formulation of factors, we identified some factors for which data is not available (e.g. different types of plantations). This might have limited our findings and analysis as we made a number of assumptions/inferences. For future research, these assumptions should be minimised.

The analysis provides a useful example of how GIS methods can be used to identify areas that are suitable for both infrastructure and mining. We found little conflict between mines and existing road networks, indicating that the planning process is to some degree addressing social-ecological values held by stakeholders, either by luck or by design. However, this analysis did not look at historic land uses to discuss land-use changes overtime (e.g. forest clearing). Furthermore, the uncertainty associated with the spatial data and social survey methods means that the results of the analysis should be treated as preliminary findings.

GIS LEAST-COST DECISION SUPPORT FOR LINEAR MINING INFRASTRUCTURE PLANNING

We used a Least Cost Pathway Analysis methodology to identify optimal pathways between two locations as a property of the cost of traveling through different land use/cover types. The method entailed using the stakeholder interview data (Chapter 3) describing social and environmental factors that were identified as being important for infrastructure planning, and characterising these in terms of orientation toward the compatibility of mining infrastructure. These environmental and social factors, characterised by spatial data layers, were then weighted according to infrastructure orientation.

A cost-surface was constructed by combining the spatial layers where high cost locations represented areas where there was low infrastructure orientation and thus low suitability for building linear infrastructure. The cost-surface was used to identify areas in the least-cost path analysis that need to be avoided and areas that were compatible with linear infrastructure. For example, areas with high biodiversity conservation value would be avoided and populated areas that may benefit from linear infrastructure are preferred by the least-cost path analysis method. Our cost-surface also included a topographical layer which identified the suitability/cost of areas for infrastructure based on the slope of the topography (e.g. steep roads are difficult and costly to construct).

We used a case study in South-East Sulawesi to demonstrate the application of the method identifying potential linear infrastructure networks for telecommunications, power lines and roads connecting mines, smelters, ports and power stations. Potential future scenarios included connecting existing locations and connecting future locations such as a planned electricity power station. We outline the spatial processing method and describe the results of the scenario analysis in terms of locations that are suitable for linear infrastructure and identify an infrastructure network that has the least impact on social and environmental values. We also provide Python script for ArcGIS 10.x that automates the processing of the weighting, combining multiple spatial data inputs at any scale (see Annexe 5). We conclude by discussing the limitations of this approach.

Our approach should not be used prescriptively. It should be included as just one of the decision support tools for land use planning. By using a participatory approach, and through multiple iterations of the model, the accuracy of the least-cost outputs and how well they reflect stakeholder preferences can be improved.

The following list provides a summary of the potential ways in which modelling outputs could be improved based on our case-study with local community members and government:

- Identify and map spatial data for sub-factors without existing data
- Improve the positional accuracy of the spatial data within areas for which the least-cost paths have been mapped through discussion with the local community.
- Improve the thematic accuracy of the spatial data in terms of how well it reflects the sub-factor that it is meant to represent.

A FRAMEWORK FOR COMMUNITY ENGAGEMENT IN MINERAL INFRASTRUCTURE PLANNING

While community participation is mandated in Indonesia through a number of legislative provisions (environmental approval regulations (AMDAL), the Spatial Planning Law and the annual planning process (*musrenbang*)), our research found that in practice community engagement is often a one off, one-way activity with limited feedback and incorporation of community views. It is imperative that future mineral infrastructure planning aims to include inclusive and responsive engagement strategies to ensure that impacted community groups' perspectives and aspirations are considered in future infrastructure projects.

The GIS-based approach to mineral infrastructure planning proposed in this project requires four stages of stakeholder engagement:

- Engaging to identify current and future infrastructure needs
- Engaging to identify and select socio-ecological factors to be used in the GIS tool
- Engaging to ground truth and collect community-generated data
- Engaging to map scenarios for infrastructure corridor development.

The stakeholders who should be involved in the above engagement activities will depend on the local and regional context, as well as the stage of engagement, however they may include:

- Provincial and regency government officials who are involved in infrastructure planning and economic development planning, including planning mineral development
- Industry bodies and mineral resource companies with operations and interests in the region
- Potentially impacted communities
- Civil society groups (CSOs)

In this research project, the four stages of engagement described above form part of a broader participatory GIS process. Participatory GIS involves practitioners engaging with local communities and other stakeholders to enable them to communicate spatial information about particular aspects of their communities (e.g. cultural resources, land tenure systems etc.) in order to influence planning processes and policies).

CONCLUSIONS & RECOMMENDATIONS

Finally, our research identifies a number of key conclusions and provides recommendations for mineral infrastructure planning in Indonesia. It also outlines a series of steps that can be followed to use the tools developed in this project for more effective, participatory planning of infrastructure corridors promoted by mining development. Key lessons and recommendations from the research are as follows:

- Early and well-coordinated mineral infrastructure planning can minimise environmental and social costs
- Government and mining companies need to work collaboratively to ensure appropriate standards for mineral infrastructure development and maintenance
- There are significant barriers to promoting better land use management in Indonesia – these might be overcome by giving responsibility to a lead government agency to bring relevant land use information together in a consistent fashion, and making that information publicly available.
- A GIS-based mineral infrastructure planning tool can enable active community participation in decision-making
- The findings of this study can serve as a productive platform to trigger further research in mineral infrastructure, participatory GIS, and integrated infrastructure planning.
- The methods and GIS tool for mineral infrastructure planning outlined in the research should be disseminated to key partners in the two case study provinces in the first instance and, ideally, to other provincial government departments involved in mineral infrastructure planning.

In addition to these key lessons and recommendations, the research also outlines a nine-step process that can be followed by land use planners and GIS officers to construct and use a participatory GIS when planning mineral infrastructure corridors and networks at the sub-national (district) level. A summary of the steps is as follows:

STEP 1: Understand existing spatial planning and sustainability frameworks in your administrative area

STEP 2: Identify current, planned and potential mineral infrastructure

STEP 3: Scope/identify any existing GIS capacity including planning tools and data

STEP 4: Select and evaluate factors to be included in the GIS (section 3.2.1 and Chapter 4)

STEP 5: Collect, manage and process available GIS data for the preliminary factors in order to generate maps

Step 5a: Collect available GIS data for preliminary list of factors identified in Step 4

Step 5b: Manage, process and address potential data quality issues (accuracy, scale, currency etc.)

Step 5c: Generate maps of intermediate list of factors and focal points/nodes (e.g. mine operations)

STEP 6: Engage stakeholders to ground truth, refine, and generate new data

STEP 7: Conduct least-cost path analysis (Chapter 5)

STEP 8: Undertake deliberations over mineral infrastructure corridor scenarios during planning workshops

STEP 9: Engage in a process of adaptive planning

CHAPTER 1: BACKGROUND / INTRODUCTION

1.1 Research Rationale

Mining and infrastructure are two interlinked sectors that can promote economic growth in Indonesia if they are managed properly. Improving local infrastructure can lead to increased private sector investment in the Indonesian mining sector. Furthermore, mining operations which tend to be located in the remote and isolated regions of Indonesia can aid the development of community infrastructure (e.g. schools, community health centres, electricity supply, roads, etc.) and therefore can contribute to reducing the existing regional infrastructure backlogs (e.g. regional roads) that are common across Indonesia.

Current infrastructure planning processes in Indonesia are unable to efficiently accommodate large investments such as mining to support basic infrastructure needs like electricity supply or the movement and export of mined materials. Furthermore, infrastructure to support mining is usually constructed with exclusive and specific purposes to support specific mining operations. One consequence of this is that it limits the benefits that mining can contribute to regional economic development, in particular because there is poor integration of planning and infrastructure provision by governments and the private sector.

There is an increasing demand for governments to better understand and appreciate the importance and benefits of managing the impacts of mineral infrastructure for communities. In Australia, the promotion of sustainable infrastructure corridors is one way to address such challenges. Infrastructure corridors aim to protect corridors from encroachment and facilitate multi-user infrastructure networks (Western Australian Planning Commission and ICC Infrastructure Coordinating Committee, 2014; Toledano, Thomashausen, Maennling, and Shah, 2014). The World Bank recently promoted resource corridors for development in Afghanistan to integrate mineral infrastructure planning for identification within the mineral resource tender processes (Stanley et al, 2011). The application of this approach however is very challenging to implement in Indonesia due the regional disparities and complexities that exist in the minerals sector.

For this purpose, the Centre for Social Responsibility in Mining (CSRM) of the Sustainable Minerals Institute at The University of Queensland (UQ), together with its Indonesian collaborator *Institut Teknologi Bandung* (ITB) in Bandung, has undertaken a collaborative research project titled: "***Socio-ecological Tools in the Development of Mineral Infrastructure***" ("the research"). The research investigates how infrastructure corridor planning associated with mining activities can take into account the principles of sustainable development. It explores key socio-ecological factors that can be considered in mineral infrastructure planning, how these factors are valued by key stakeholders and, subsequently, how they can be incorporated and translated into a Geographic Information System (GIS) based tool and methodology that supports sustainable regional mineral infrastructure planning in Indonesia.

The research was funded by the Indonesia Infrastructure Initiative (IndII) through the Australia – Indonesia Infrastructure Research Awards (AIIRA) from May 2014 until December 2015. The AIIRA program aims to enhance the skills and informed roles of academic and civil society organisations in Indonesia's infrastructure policy and planning processes by promoting collaboration between International research institutes such as CSRM within the Sustainable Minerals Institute, the University of Indonesia and an Indonesian University, i.e. ITB. The research findings are expected to improve infrastructure planning policies in Indonesia, including at the regional level, as well as to strengthen the research capacity of ITB in the area of mineral infrastructure planning.

1.2 GOAL AND OBJECTIVES

1.2.1 GOAL

The lack of quality widespread public infrastructure such as roads, rail, water, and power supply systems can be a key determinant for mining companies considering investing and undertaking mining activities in Indonesia. Consequently, many mining proposals comprise the development of such infrastructure to complement companies' mining activities. However, the development of mineral infrastructure can also have significant social and environmental impacts. For example, the construction of roads or ports can disrupt protected areas, sensitive habitats and important lands for community livelihoods. The development of industrial roads can encourage population in-migration and expose local people to social risks such as prostitution, alcohol abuse and infectious diseases (e.g. Sexually Transmissible Infections).[2] Land acquisition for infrastructure development can also disrupt livelihoods and lead to land disputes and conflict with communities. These issues are not adequately addressed by current approaches to planning in Indonesia.

This collaborative research aims to support government planners in addressing such challenges proactively by: providing evidence-based research on how current mineral infrastructure planning has been occurring; and providing recommendations for better mineral infrastructure development in regional planning by considering key social and ecological factors. By having this approach, planners can mitigate or avoid (i.e. 'engineer out') future social and environmental problems. The introduction of sustainable and multi-user mineral infrastructure corridors with sensitivity to existing socio-ecological conditions can also contribute to the achievement of sustainable development in the mineral rich regions in Indonesia. Subsequently, the main goal of this research is to answer two main research questions:

1. What are the key factors that need to be included in promoting sustainable infrastructure development associated with mining industries?

[2] The adverse health impacts of extractive industries on Indigenous Peoples are well-documented.

2. How can these factors be incorporated into a tool that can be used to better plan infrastructure development associated with mining industries in resource-rich regions of Indonesia?

1.2.2 Research Objectives

In answering the research questions provided in Section 1.2.1, the objectives of this research comprise:

1. Benchmarking key socio-ecological factors for mineral infrastructure planning
2. Evaluating current mineral infrastructure development and investigating its associated socio-ecological impacts
3. Developing an optimization model using least-cost path analysis as a GIS modelling tool for future infrastructure corridors planning
4. Recommending a framework for community engagement in mineral infrastructure planning in Indonesia

1.2.3 Expected Broader Impacts Of The Research

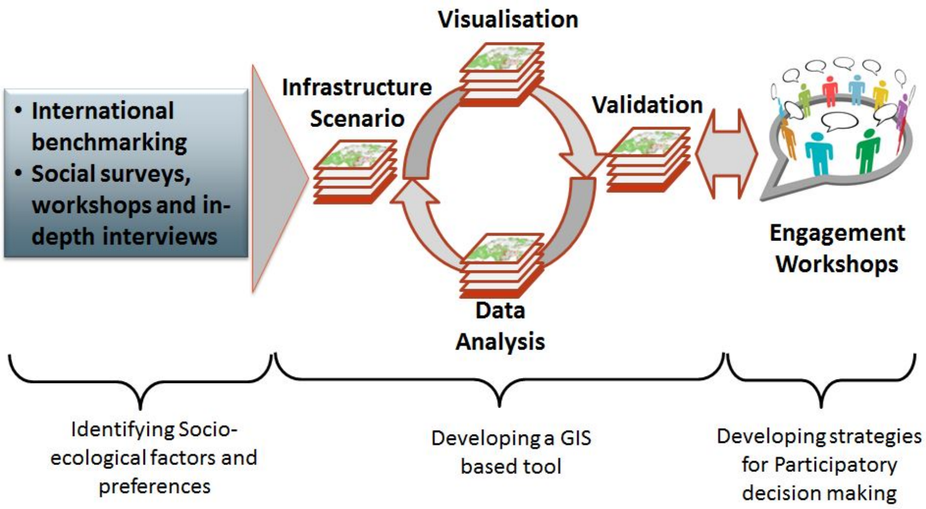
We expect that the research findings can inform the development of mineral infrastructure policies in Indonesia. The GIS tools provided in this collaborative research can provide a platform for further research in this field and better scientific engagement in Indonesia's infrastructure planning.

It is also hoped that this research will enrich the knowledge and literature of mineral infrastructure research in Indonesia and globally. The adoption of the tool and protocols by Indonesian governments and relevant stakeholders in their planning and decision making processes can also help create an environment conducive to mineral infrastructure investment and, ultimately broader economic growth in Indonesia.

1.3 Research Activities, Timeframes And Deliverables

This research was carried out in three interlinked phases as summarised in Figure 1.1.

Figure 1.1 Research Approach



The details of the research activities, timeframes and deliverables are elaborated below.

<u>Phase one (April to October 2014)</u> – identifying socio-ecological factors to be considered during mineral infrastructure planning. The activities and deliverables comprised:

Research activities

- Desktop study and literature review to understand the mineral infrastructure concept and socio-ecological factors considered in its planning
- A field trip in Indonesia (Jakarta, East Kutai and South Konawe) was undertaken in October 2014. The aim of this trip was to investigate the perception of key stakeholders about the socio-ecological factors needed in mineral infrastructure planning. In-depth interviews and a survey were also undertaken to understand social and ecological impacts from mineral infrastructure development in East Kutai and South Konawe Regencies.

Deliverables

- Socio-ecological factors were identified through literature review and surveys
- Power-point presentations to key stakeholders in Indonesia through two group meetings in East Kutai Regency and South East Sulawesi Province
- A mid-term report submitted to AIIRA in October 2014.

Phase two (October 2014 to March 2015) – developing a GIS based tool. The research undertaken comprised:

Research activities

- Data collection and gap analysis
- Infrastructure scenario development
- A second fieldwork trip to Indonesia (Andoolo and Kendari) was conducted in March 2015 to validate data and establish scenarios for GIS modelling
- Producing maps for visualizing infrastructure planning scenarios

Deliverables

- Geospatial data were acquired and analysed
- Meetings with key stakeholders in South Konawe to discuss the potential mineral infrastructure development for GIS modelling
- Two GIS models were developed together with data layers

Phase three (April to December 2015) – developing strategies for participatory decision making. The research activities and deliverables include:

Research activities

- Information and data from in-depth interviews, dialogue and meetings from fieldtrip in Indonesia in October 2014 and March 2015 were analysed to inform participatory models for mineral infrastructure planning

Deliverables

- All findings were compiled, analysed and triangulated
- Draft final report was submitted in April 2015.
- Final report was submitted subsequently after receiving feedback from the panel in December 2015.

1.4 Case Studies

In this research a case study approach was undertaken. The unit of analysis was the regency level with two case study regions selected, namely:

a. East Kutai Regency in East Kalimatan Province, which represents an established (brownfield) mining region that is dominated by a single major and large mining operation in the area

b. South Konawe Regency in South East Sulawesi Province, which represents a newly growing (Greenfield) mining region that is dominated by several medium/small scale mining operations.

The use of a case study approach serves three purposes:

- to understand key stakeholders' opinions and perceptions about socio-ecological factors they deemed important and should be considered in mineral infrastructure planning, as well as how they valued and prioritised these factors as captured through in-depth interviews and surveys
- to apply GIS proximity analysis (a retrospective and evaluative analysis) in East Kutai case study to characterise how mineral infrastructure development has proceeded in a region
- to apply the identified key social and ecological factors in a GIS progressive modelling for integrated mining infrastructure planning (i.e. GIS least-cost path analysis) in the South Konawe case study.

1.4.1 East Kutai Regency

East Kutai Regency is located in the East Kalimantan Province (Figure 1.2) and was established in 1999 as a result of decentralisation policy in Indonesia. The regency has an area of 35,747.50 km^2 and a population of 285,743 in 2012.[3] A large portion of land falls within the boundaries of Kutai National Park. There are 18 districts and 135 villages within this regency with Sangatta being the capital city.

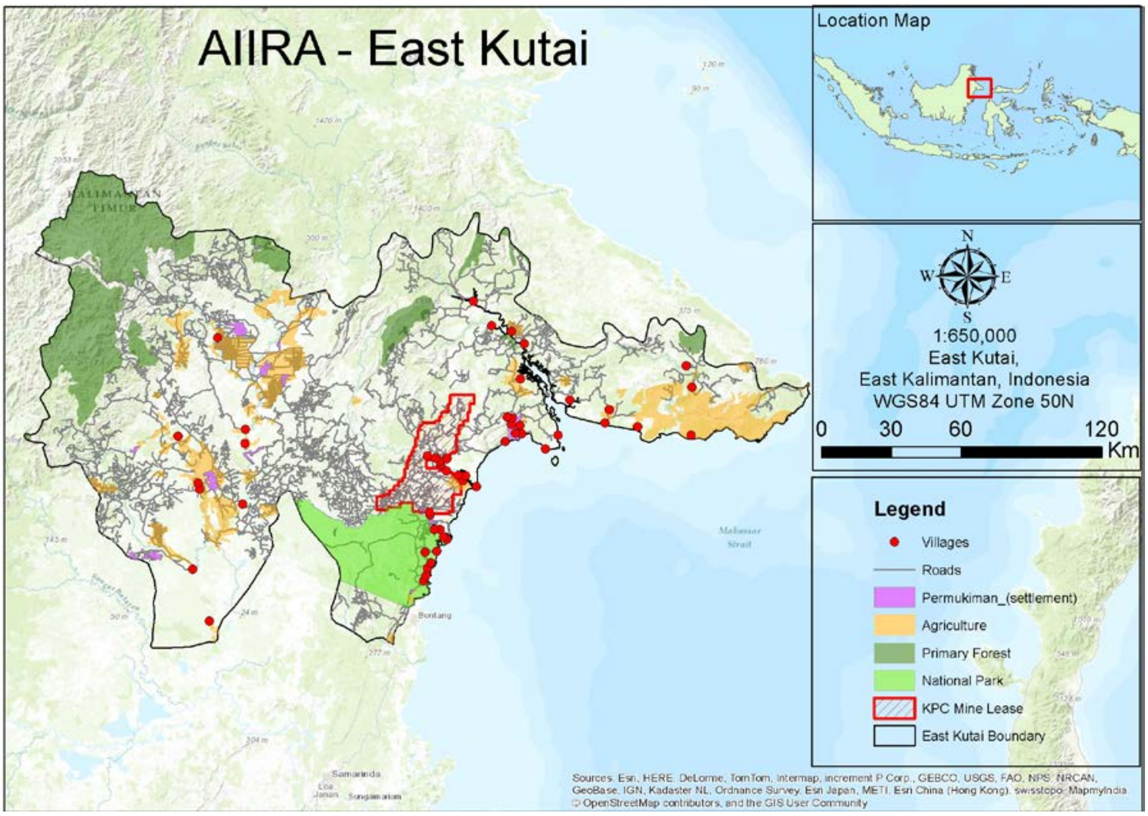
The main economic activity in the region is mining, which contributes around 50 percent to the regency's economy (Surjono et al, nd). PT Kaltim Prima Coal (PT KPC) owns mining concession areas of 90,960 hectares including the two mining areas of Sangatta and Bengalon. PT KPC was originally owned by BP and Rio Tinto with exploration undertaken between 1982 and 1986. With estimated reserves of 112 million tons of export quality thermal coal, construction began in 1989 and the mine was commissioned in 1991. In mid-2003, PT KPC was sold to PT Bumi Resources. The Sangatta mine has a mine-life up to 2020.

Existing mineral infrastructure was mostly built by PT KPC to support their mine to port operations. Also, there is evidence that PT KPC has supported regional and community infrastructure in the region. This will be discussed further in Chapter Two.

Besides PT KPC, there are other mining investments planned in the region. The region is also a growing region for oil palm plantations.

[3] http://kutimkab.bps.go.id/index.php?hal=tabel&id=4 [Retrieved 2 March 2015]

Figure 1.2 East Kutai Regency



1.4.2 SOUTH KONAWE REGENCY

South Konawe Regency is located within South East Sulawesi Province (Figure 1.3). The regency is relatively new, having separated from its original regency of Konawe in 2003. The regency has an area of 451,420 Km^2 and a population of 275,234 (2012).[4] There are 22 districts and 343 villages, with Andoolo being the capital city.[5]

The main economic activities in the region are subsistence agriculture (cassava, corn, rice paddy fields, bananas, etc.) and small to medium scale farming or plantations (such as cocoa, coconuts and cashew nuts). The region experienced a mining booming in the period of 2011 to 2013 however mining has been slowing down since the introduction of mineral processing and refining policies in early 2014. The region is expected to still accommodate small and medium scale mines. During the course of

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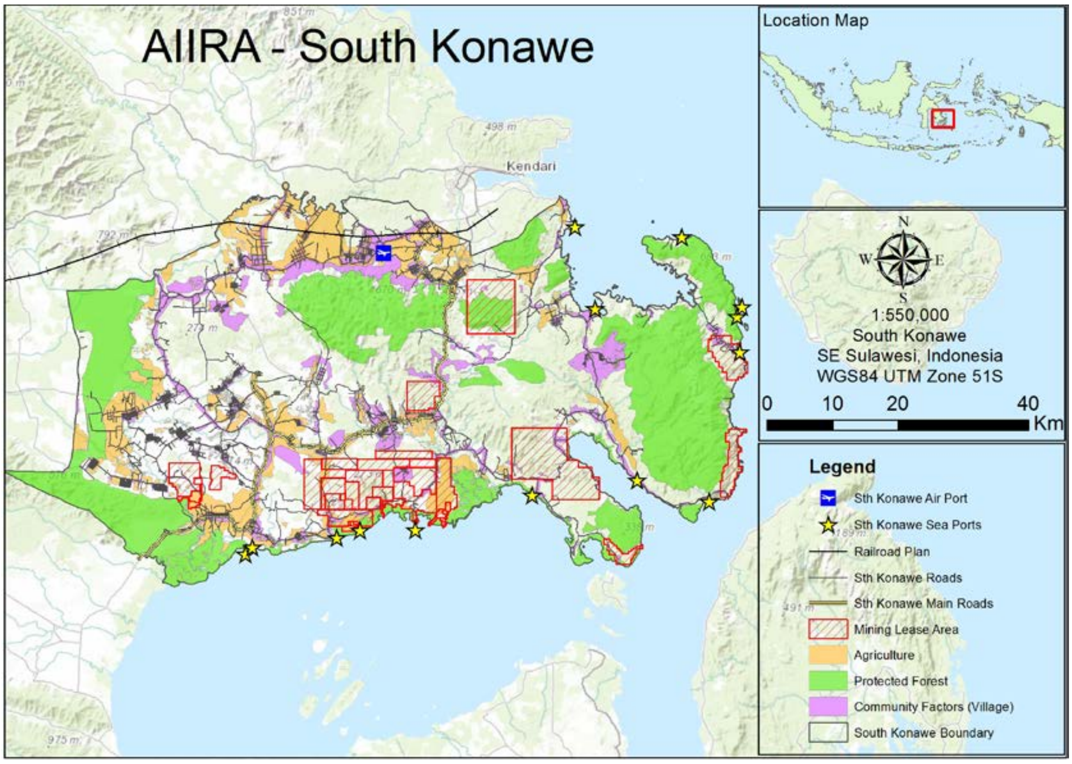
4 http://regionalinvestment.bkpm.go.id/newsipid/demografipendudukjkel.php?ia=7408&is=37 [retrieved 20 April 2015].

5 http://kendari.bpk.go.id/?page_id=391 [retrieved 20 April 2015].

this research several nickel smelters were being constructed. Existing mineral infrastructure in the region tends to be scattered within and outside company lease areas with poor standards, as further discussed in the Chapter Two.

Figure 1.3 South Konawe Regency



1.5 RESEARCH ETHICS AND IN-COUNTRY ENGAGEMENT

The research has been conducted in accordance with the ethical guidelines of the Behavioural and Social Sciences Ethical Review Committee at the University of Queensland.

These guidelines stipulate that all participants be informed that their contribution to the research is voluntary and confidential. All data has been aggregated, and any quotes or other interview material reported for this study has been de-identified to protect individual confidentiality.

In accordance with ethics requirements, the research teams do not mention individual names however the name of institutions and positions that have been engaged for this study may be identified. In stating this, the research has conducted several workshops, focus groups and surveys with the summary as provided below:

- **In-depth interviews and social surveys:** UQ and ITB researchers have conducted 37 interviews/social surveys with key stakeholders in Jakarta, Sangatta (East Kutai, East Kalimantan), Kendari (South East Sulawesi), and Andoloo (South Konawe, South East Sulawesi)

- **Meetings and focus groups:**
    - four meetings either individual or in groups of 3 to 5 persons were conducted within national government representatives and a mining company representative in Jakarta
    - 19 meetings with subnational governments, company representatives, and civil society/community members in East Kutai Regency and Southeast Sulawesi Province (including South Konawe Regency)
    - two focus groups with a size of between 30 to 50 persons (each was held in East Kutai and Kendari)

1.6 Linkages with IndII, DFAT and GOI infrastructure objectives and policies

The research aims to contribute to the overall Indonesia Infrastructure Initiative (IndII) goal in Indonesia as stated in its website:[6]

> **"to promote economic growth by working with the Government of Indonesia to enhance infrastructure policy, planning and investment"**

Also, the research aligns significantly with the current Indonesian Government's aim of boosting infrastructure development in the country, especially in remote parts of the country in order to improve regional connectivity so as to attract regional investments. With the strong contribution of the mining sector to Indonesia's economy, it is expected that mining can also play an important role in filling the infrastructure bottleneck to remote parts of Indonesia. Consequently, we expect that the economy of remote communities can be improved through sustainable investments. Specifically, we expect that the outcomes of the research can positively support Australian DFAT specific missions in Indonesia for promoting 'sustainable economic development' and 'opportunity for all' as further described in this section.

1.6.1 Promoting Sustainable Economic Development

The research supports the GoI in its objective of promoting sustainable economic development in a number of ways, including: 1) helping create an environment that is more conducive to private sector investment in infrastructure by enabling social and environmental challenges to be considered earlier in mineral infrastructure development; 2) investigating potential governance mechanisms that can facilitate horizontal and vertical coordination between government agencies involved in infrastructure planning; and 3) supporting broad-based economic growth in rural and remote areas.

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[6] http://www.indii.co.id/index.php/en/

Creating an environment more conducive to investment in infrastructure

The research provides a more proactive method of addressing social and environmental challenges to mineral infrastructure development and planning. The proposed GIS tools enable socio-ecological factors, including patterns of land use, community factors and sensitive environmental areas, to be considered earlier in the planning process when corridors are delineated. The GIS tools can suggest the areas for future infrastructure development to be carefully defined so as to minimize future problems. The tools therefore enable government planning authorities to be proactive, as opposed to reactive, in addressing such risks. This can reduce project delays and provide greater certainty for investors.

Improving governance mechanisms to support coordination between government agencies

Through the research activities, researchers have engaged with various Indonesian Government Agencies through meetings, focus group discussions and workshops to investigate how coordination mechanisms between government agencies can be strengthened in mineral infrastructure planning. Strong planning mechanisms and inter-agency coordination are essential to the success of the resource corridor approach (Sustainable Development Solutions Network, 2013) and essential if socio-ecological factors are to be incorporated into mineral infrastructure planning. Chapter Six provides suggested strategies on how inter-agency coordination as well as community engagement can be improved.

Support for broad-based economic growth in remote and rural areas

The basic premise of the resource corridor approach is that mineral resource infrastructure can be transformed or established to create a viable and diversified regional economy that extends beyond mining. This is achieved by leveraging the investments that mineral resource companies must make in infrastructure to service their operations, so that there are wider economic and social benefits from mineral development in a region. With many mining operations located in rural or remote regions of Indonesia, the resource corridor approach has the potential to promote diverse economic activity and rural development.

1.6.2 Promoting Opportunities For All

This research investigates ways in which input from local communities can be systematically considered prior to project development in the planning stage, including planning of resource corridors. One of the main outputs of the research is a set of protocols (Chapter 4) that can provide guidance for government planning authorities to obtain the input of local people and other stakeholders. Developing such a tool and protocols offers a number of important benefits, including:

- Enabling negative social and environmental impacts of infrastructure development to be avoided rather than being addressed once projects are underway; and

- Supporting development of infrastructure that meets the needs of all citizens in a region, including those who are most vulnerable. For example, participatory infrastructure planning may result in the development of trunk infrastructure that would give small farmers better links to markets and reduce transportation costs.

1.6.3 Gender, Social Inclusion, Environment Issues

Although this research does not specifically target gender and social inclusion issues, the research findings are intended to improve the participation of women and marginalised groups in decision making processes that affect them. Specific community engagement strategies are suggested as one of the deliverables of this research. In regard to environmental issues, it is clear that our research promotes sustainable mineral infrastructure planning and suggests a methodology and tools on how environmental and socio-environmental issues have to be considered in mineral infrastructure planning.

1.6.4 Lessons Learned From Partnership Approach

This research promoted active collaboration not only between CSRM and RG-RCIS but also with other Indonesian partners such as sub-national governments and companies.

Through the partnership established in this research, CSRM has facilitated two team research members to participate in the International Mining for Development Centre (IM4DC)'s training courses at the University of Queensland. They include:

- Mohamad Syukril, our research counterpart from South East Sulawesi Government (BAPPEDA) participated in the IM4DC course on Resource Governance and IM4DC conference in August/September 2014 at the University of Queensland (UQ).

- Dr Shanti Rachmat, the research team member from Institut Teknologi Bandung (ITB) participated in the IM4DC course on Community Aspects in Resource Development and IM4DC conference in August/September 2014 at UQ.

For the implementation of research activities, both research teams found that there have been no major issues experienced under this multiple collaboration however, there were some logistical challenges which could be addressed in future collaborations, such as:

- Conflicting schedules of different parties caused some delays in the commencement of research
- The field work trips were delayed due to multiple activities happening at the same time with our regional partners (e.g. scheduled after the Ramadhan and Idul Fitri in Indonesia as well as in the planning month of Musrenbang activities).

Further details about the partnership and its project management and administration (including the role and profile of research team members) are provided in Annexe 2.

1.7 Report Structure

Chapter 1 – **Introduction** provides the rationale and background of the study and lessons learned from our partnership approach.

Chapter 2 – **Mineral Infrastructure and Planning Issues** provides the overall setting of mineral infrastructure planning and its relevant practices in Indonesia.

Chapter 3 – **Socio-ecological Factors for the Mineral Infrastructure Planning** identifies relevant and measurable socio-ecological factors that can be incorporated into GIS tools.

Chapter 4 – **A Framework for Community Engagement in Mineral Infrastructure Planning** proposes a framework for engaging communities and other stakeholders throughout the mineral infrastructure planning process.

Chapter 5 – **GIS Least-cost Decision Support for Linear Mineral Infrastructure Planning** develops a method to identify optimal pathways for linear mining infrastructure using South Konawe Regency, Southeast Sulawesi Province as a case study.

Chapter 6 – **Conclusion and recommendations** summarises the key lessons learned from this research and also provides into a practical guide for participatory GIS for mineral infrastructure corridor planning. This chapter also provides key recommendations for future research and actions.

CHAPTER 2: MINERAL INFRASTRUCTURE AND PLANNING ISSUES

2.1 SUMMARY

This chapter describes the overall context for mineral infrastructure planning in Indonesia, including relevant concepts, practices, and key issues. Interviews with relevant practitioners both from public and private sectors, as well as community representatives such as civil society groups, were conducted during the field visits in October 2014. Some key points are summarised below:

- The chapter focuses on three categories of mineral infrastructure, including: i) infrastructure to support the mine operation and its value chains; ii) community infrastructure as part of companies' CSR programs; and iii) regional infrastructure to stimulate growth). We observed these infrastructures in both case study regions and we found that large scale mining has more diverse and better standards of mineral infrastructure in comparison to the medium/small scale mine operations.

- Mineral infrastructure planning in Indonesia is not specifically defined – consequently, it cannot be separated from infrastructure and regional planning systems in Indonesia. There are multiple agencies and multiple regulatory requirements involved in these. Key respondents suggested that coordination amongst sectors and different levels of government has been a challenge.

- Our findings indicate that socio-ecological factors are often not considered in mineral infrastructure planning. Most participants had difficulty in describing the types of socio-ecological factors that may be considered in mineral infrastructure planning. However, some participants gave general feedback in relation to the socio-ecological factors considered in the development of spatial planning and Environmental Impact Assessment (AMDAL) processes. We conclude that key respondents' understanding of environmental factors is well-defined in comparison to social factors.

2.2 TYPES OF MINERAL INFRASTRUCTURE

Mineral infrastructure planning is an integrated planning approach, combining infrastructure planning and resource sector development. The approach involves consideration of social, economic and ecological factors in the planning of infrastructure development in mineral regions. It aims to maximise the benefit of mining development by ensuring broader access to mine infrastructure and maintaining high social and ecological standards. For the purpose of this research, we define mineral infrastructure into three categories, including:

a) Infrastructure to support the mine operation and its value chains (e.g. roads, railways, ports, water and power systems, etc.).
b) Community infrastructure as part of company's targeted CSR effort to promote community development and gain a social license to operate (e.g. schools, hospitals, etc.).
c) Regional infrastructure that can stimulate growth and makes a contribution to regional development. This may occur when:
    - A mining company gives communities and other stakeholders in a region access to their roads, power and water supply systems
    - Governments provide integrated basic infrastructure to support economic investments. When governments have limited financial capacities to develop such infrastructure, they can partner with mining companies to develop public infrastructure as part of a public-private partnership.

To further understand different type of mineral infrastructure, UQ and ITB researchers visited two mining operations: a large mining operation in East Kutai Regency and a medium scale mining operation in South Konawe Regency in October 2014. The description of these mining operations and their mineral infrastructure are described below.

2.3 Observed Mineral Infrastructure in Two Case Study Regions

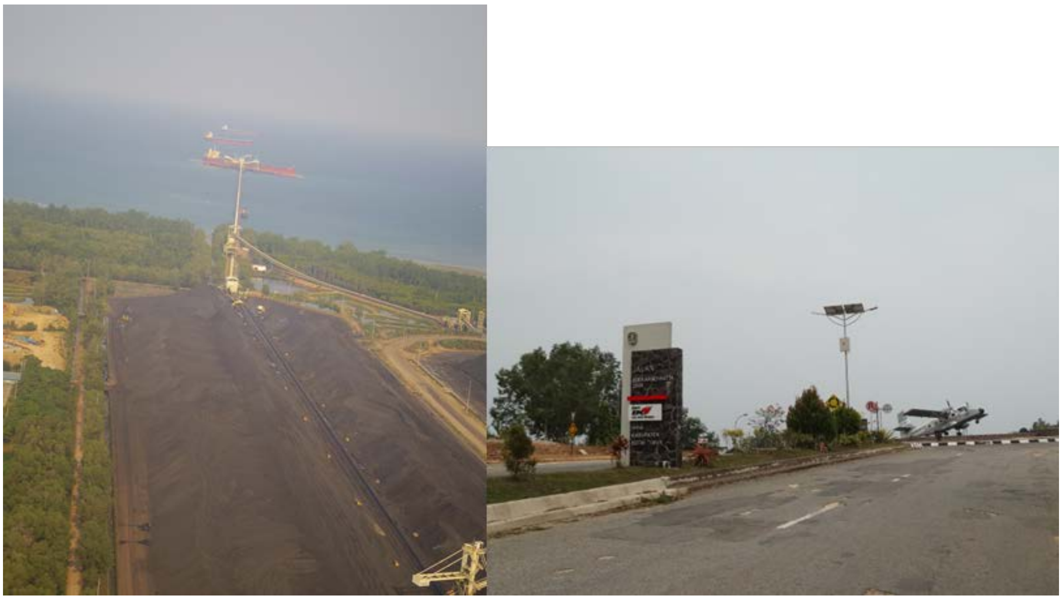
2.3.1 Large Scale Mine And Its Infrastructure

The large-scale mine that the team visited in East Kutai Regency is the largest coal mining company in Indonesia producing 50.7 million tonnes per year. Operations started in 1991 and the mine has an expected mine-life until 2021. The mine exports coal both domestically and internationally. The company currently employs 5,135 people directly and more than 16,000 indirectly through subcontractors. The mine lease site is about 90,000 hectares and covers four municipalities in the East Kutai Regency. The mine is serviced by two towns, including Sangatta Utara (90,000 – 100,000 people) and the mine company developed town, which originally was designed to service its employees but now is open to non-mine employees to live.

The large-scale mine company has developed a range of infrastructure since it began operating 1992. In terms of mine-supporting infrastructure, the site has a coal crushing facility, washing plant, 17 kilometre overland conveyor belt and port facility at the end of a two kilometre jetty to support the mine's processing and transportation activities (Figure 2.1 A). All of the large-scale mine's operation-supporting infrastructure is contained within the company lease area and thus the company has not had to acquire additional land from government and/or the community for infrastructure developments.

The large-scale mine company has contributed to the development of regional infrastructure in East Kutai; most notably through the construction of the Soekarno-Hatta Road in 2009-2011 (Figure 2.1 B). The eight kilometre two-lane road was built by the company upon request from the Regency Government to build a "safer alternative road" for communities. The road was built in two stages (first lane built in 2009 and the second in 2011) and its specific location was predetermined by the Regency Government. Once construction was complete, the large-scale mine company handed the road over to government for management and maintenance.

Figure 2.1 (A) Mine-supporting infrastructure and (B) Public road constructed by the company



In terms of CSR infrastructure, the large-scale mine company stated that 60% of their community development work is allocated to infrastructure development (large-scale mine company, 2014). Specific company CSR developments include constructing the Sangatta Hospital ($US 60 million project) (Figure 2.2) and local school buildings, and providing housing in the region (the company built 70 houses in 2013-14, total $US 5 million project). Funding for such developments are allocated and controlled by the large-scale mine company, but are based on the company's social mapping[7] and government/community consultation activities (large-scale mine company, 2014).

[7] The large-scale mine company identified all key social actors in their operating region and outlined each groups' ideologies (e.g. for or against mining), power and level of influence (large-scale mine company, 2014).

Figure 2.2 Company Funded Hospital

2.3.2 Medium Scale Mine And Its Infrastructure

The medium-scale nickel mine is in Tinanggea District, South Konawe, Southeast Sulawesi. The mine site lease is about 800 hectares located within a 2,580 hectare plantation area, which is owned by a well-known food brand. The food brand has invested in South-East Sulawesi since 1960 mainly in cashew plantations. The company expanded its cashew plantation investment in South Konawe through a sub-company. The plantation however was not successful and that sub-company transferred its business to a nickel mining business in 2010. The medium-scale mine employed 560 workers during its peak operation. In early 2014, the company stopped nickel production and reduced its employment to 189 people due to the national policy ban on raw material export.

During the field visit (October 2014), the research team was informed that there are currently more than 500 mining licenses (IUPs) issued to medium- and small-scale mining companies in Southeast Sulawesi Province. South Konawe Regency hosts about 17 IUPs for nickel mines, including the visited medium-scale mine. Of these 17 mines, the medium-scale mine visited is the only mine that is still 'active'. However, the company is not currently exporting.

The medium-scale mine company has constructed a range of mine operation-supporting infrastructure both on and off their direct mine (and cashew plantation) lease area. Currently the medium-scale mine company (under a sub-company) is constructing an on-site nickel smelter ($100 million) in response to the government issued ban on the export of raw materials (mandated by Law No. 4 of 2009) (Figure 2.3). The smelter construction is expected to be completed by late 2015 and produce

Nickel Pig Iron with capacity of 40 – 50,000 tons annually. Once the smelter is fully operational, it is expected the company will employ an additional 1,000 workers.

The company has also constructed a hauling road and port facility to assist with transportation of the nickel. Given the relatively small mine site, both developments have occurred outside the company's lease area. The hauling road is unpaved and surrounded by community agricultural land on either side (e.g. rice paddy fields, ponds and grazing land) (Figure 2.4). The company stated that compensation was paid to all landowners whose land was acquired for these developments; however a review of the literature reveals there have been ongoing disagreements between the company and four villages in South Konawe about land ownership rights and appropriate compensation[8] (Antara News, 2012).

Figure 2.3 Early construction of nickel smelter

[8] http://antarasultra.com/berita/263370/dprd-sultra-mediasi-sengketa-ifishdeco-dengan-warga [retrieved 10 October 2014]

Figure 2.4 Medium-scale mine hauling road to port and surrounding land uses

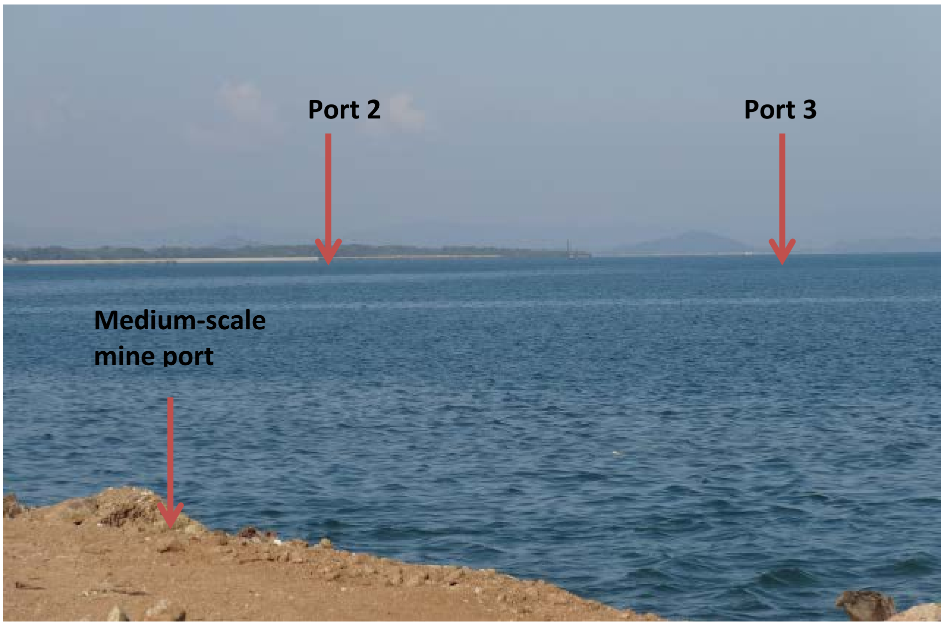
The company's port facility was constructed in 2012 and built on reclaimed land. The civil society respondents claimed that about 0.5 hectare of mangrove vegetation was removed during construction. The port does not use any form of silt traps to minimise sedimentation and runoff into surrounding marine water ways (Figure 2.5). Two additional ports (one government port and another mining company port) have been developed approximately 30 kilometers to the east of the visited medium-scale mine port (Figure 2.6).

During interviews, the company suggested that they have spent about AUD $900,000 for CSR programs from 2011 until now. The company however mentioned that this total budget allocation including budget spent for monthly cash compensation for farmers affected by their mine and transport activities. Apart from this, the company through its CSR programs has also contributed to several infrastructure developments including:

- the construction of bridges
- drill wells for agricultural irrigation
- construction of houses of worship
- an ambulance car for the local hospital.

Figure 2.5 Port facility looking back to coastline

Figure 2.6 Additional ports looking east from the visited medium-scale mine port



2.4 Overview Of Mineral Infrastructure Planning In Indonesia

2.4.1 Key Government Agencies Involved In The Regulation Of Infrastructure Development And Provision

A large number of Ministries and government agencies are involved in the planning, financing and implementing of infrastructure projects in Indonesia. At the central Government level there are two agencies with coordinating roles in infrastructure development: the Coordinating Ministry for Economic Affairs, which is tasked with coordinating infrastructure development and other economic activities that overlap the areas of responsibility of different Ministries; and the Ministry of National Development Planning (BAPPENAS), which is responsible for development planning and policy formulation, including in the area of large-scale infrastructure development.

Other central government agencies that play an important role in infrastructure development in Indonesia include the Investment Coordinating Board (BKPM), which is responsible for creating an investment climate conducive to private sector participation, and the Bureau of Logistics (BULOG), which is involved in many infrastructure initiatives, particularly in the agricultural sector.

Control over the infrastructure budget is held by the Ministry of Finance, which allocates infrastructure funding to several other Ministries. The Ministries have control over strategic planning, budget oversight and policy development for particular classes of infrastructure (Table 2.1) (Gerber, 2013). The two biggest recipients of this funding are the Ministries of Public Works and Transportation. Adding to this complex chain of responsibility is the role played by the state-owned enterprises (SOEs), each of which has its own budget and ability to develop projects under the instruction of their affiliated Ministries.

One significant problem with the governance of Indonesia's infrastructure is that there limited coordination between the many government agencies that play a role in infrastructure development (OECD, 2010). This reflects the lack of a hierarchy of decision-making power and the fact that no single agency has sufficient influence and expertise to plan and implement infrastructure development in an efficient and timely manner. Although the Coordinating Ministry for Economic Affairs and BAPPENAS both have coordinating roles that encompass infrastructure, neither of these agencies has sufficient political influence to determine the policy direction within the Ministries. Ironically, one outcome of this is that come year end the infrastructure budget is often not spent.

The government has taken steps in the past to address such problems by creating inter-Ministerial agencies, such as the Policy Committee for the Acceleration of Infrastructure Provision (KKPPI) but these agencies also have a limited concrete power to make decisions (OECD, 2010).

Table 2.1 Infrastructure Type and Ministry Responsibility

Type of Infrastructure	Responsible Ministry
Ports, airports and railways	Ministry of Transportation
Water and sanitation, roads, irrigation, and main line canal systems	Ministry of Public Works
Energy generation and distribution	Ministry of Energy and Mineral Resources
Grain storage and handling	Ministry of Agriculture
Industrial zones, communication technologies, various types of infrastructure equipment (e.g. water and sewerage equipment etc.)	Ministry of Industry

Source: Gerber, 2013

The coordination of infrastructure provision in Indonesia is made even more challenging as a result of the devolution of greater authority to the regional governments following the decentralisation law of 2001. The decentralisation program transferred many of the responsibilities for infrastructure provision to the regions (World Bank, 2004). As a result, it is now not always clear which level of government is responsible for the provision of particular services. Further, regional agencies may have priorities and agendas for economic and infrastructure development that are not in line with those of those of the central government.

2.4.2 Recent Trends In Infrastructure Development

Historically, Indonesia's infrastructure has mostly been developed and maintained by the public sector. However, this has gradually been changing and the government, aware that the slow pace of infrastructure development is acting as a drag on the economy, has assigned a much greater role for the private sector, primarily through public private partnerships (PPP).

In May 2011, the Coordinating Ministry for the Economy launched the Master Plan for the Acceleration and Expansion of Indonesia's Economic Development, also known as 'MP3EI'. The Government hopes that MP3EI will help Indonesia become a top 10 global economy by 2025 (Business Monitor International, 2013). The plan has three interrelated components: the creation of six infrastructure corridors in order to foster centres for economic growth in the major island groups; strengthening of connectivity between these centres of growth; and strengthening human resource capacity, including in the area of research and development, in each corridor. A major focus of MP3EI is on infrastructure development. The Government hopes to attract a total of $500bn in investments in manufacturing facilities, public works, science and technology development, human resources – with $250bn of this earmarked for infrastructure (Gerber, 2013). The government expects that much of this investment will come from the private sector. However, the plan has been widely criticised as being unrealistic and it has been reported that the momentum under the plan is dwindling (Gerber, 2013).

2.4.3 Indonesia's Spatial Planning System

Economic development planning, including infrastructure planning, must conform with the spatial plans that exist at national, provincial and district/city levels. Indonesia introduced its most recent spatial planning law in 2007 (Law 26/2007). Under the law and associated regulations, spatial planning has a hierarchical structure. At the highest level there is a national spatial plan, followed by plans at provincial and district/city levels. The most detailed spatial plans are those developed at the district/city level. These spatial plans must conform to the provincial plan, which in turn must conform to the national spatial plan (Sutanta, 2012).

The national spatial plan is coordinated by the National Coordinating Agency for Spatial Planning (BKPRN). This agency also supervises and evaluates development of the spatial plans produced by the 34 provinces and numerous districts and cities. However, under the Law on Regional Autonomy (Law 32/1999), many national government activities, including spatial planning, have now been handed over to the district and city governments.

Spatial plans at the city level are coordinated by the Regional Coordinating Board for Spatial Planning (BKPRD) and led by the Regional Development Planning Agency (BAPPEDA). A variety of other local government agencies have input into the development of these spatial plans, including providing data, such as the Departments of Public Works and Agriculture and Forestry, as well as the Geological Agency and local branch of the National Land Agency (BPN).

Despite the devolution of spatial planning to the local (i.e. district/city) level, provincial and national government agencies continue to play a critical role in the spatial planning process. For example, the technical aspects of the district/city spatial plan must be approved by the regional BKPRD before going to the next stage of the approval process. Next, the draft spatial plan is sent to the local legislative body (DPRD) where draft local regulations are written. Finally, the draft of these regulations is sent to the provincial government and the National Coordinating Board (BKPRN) for approval, at which stage they come into legal force (Sutanta, 2012).

The technical components of the spatial planning process are usually undertaken by consulting firms under the supervision of BAPPEDA. This process theoretically provides an opportunity for the public, other government agencies, and parliamentarians to have input, for example through public hearings, workshops and parliamentary meetings.

One of the key challenges of spatial planning in Indonesia is being able to obtain reliable spatial data. Spatial data is not available in many local governments and, where it does exist it is often out of date, not in the correct format or at the wrong scale. In addition, not all government agencies have access to Geographic Information System (GIS) software or staff may not have the expertise/capacity to utilise it.

2.4.4 Consideration Of Social And Environmental Factors In Infrastructure Development Planning

As with all development activities that are likely to have an environmental impact, mining projects are required to carry out environmental impact assessments (EIAs), known as AMDAL (Devi and Prayogo, 2013). This requirement applies to both to the direct mining operations (e.g. pits) and associated infrastructure (e.g. processing facilities, tailings damns, roads, rail etc.).

Our interview findings however indicate that socio-ecological factors are not often considered in mineral infrastructure planning. Most respondents had difficulties in describing the types of socio-ecological factors that may be considered in mineral infrastructure planning. Some respondents gave general feedback in relation to the socio-ecological factors considered in the development of spatial planning and Environmental Impact Assessment (AMDAL) processes.

We also found that key respondents had a greater understanding about environmental factors than social factors in relation to mineral infrastructure planning. This implies that there are no formal processes or procedures for considering social factors in mineral infrastructure planning. Most respondents however believed that infrastructure such as roads and ports provide positive benefits to communities, in particular because they open up remote locations and support the local economy.

2.4.5 Mining And Infrastructure Development

The establishment of a Greenfield mineral development in Indonesia often entails the construction of a significant amount of new infrastructure, such as access and haulage roads, rail lines, port facilities, power generation and distribution networks, and pipelines (PWC, 2012). There are a large number of regulations that apply to the development of mineral infrastructure in Indonesia. There are also a range of government actors who have the authority to issue business licenses for different types of mineral infrastructure, as shown in Table 2.2.

The body/authority responsibility for issuing licenses to build infrastructure differs according to the type of infrastructure and administrative level involved. For example, in the case road infrastructure to service mineral developments it is the responsibility of the Mayor or Regent if the road is constructed within a single Regency. However, if the road crosses a provincial boundary, responsibility lies with the Minister of Energy and Mineral Resources.

Table 2.2 Regulation of Infrastructure Developed as Part of a Mining Business

Type of infrastructure	Issuer of business license	Applicable regulations
Special port / terminal	- Minister of Transport	- Law 17/2008 - Law 4/2009 - Presidential Reg. No. 61/2009
Roads	- Mayor/Regent (if within a Regency) - Governor (if cross-regency within a province) - Minister of Energy & Mineral Resources (if cross province)	- Law 38/2004 - Govt. Reg. 34/2006 - Govt. Reg. 8/1990 - Govt. Reg. 40/2001 - Govt. Reg 15/2005 - Law 4/2009
Power plants /transmission	- Mayor/Regent (for power transmission within a Regency) - Governor (for power transmission cross-regency within a province) - Ministry for National Transmission	- Law 30 /2009 - Govt. Reg. 3/2005 - Govt. Reg. 10/ 1989 - Law 4/2009
Railways	- Ministry, Governor or Mayor, depending on the area covered by the railways	- Law 23/2007 - Govt. Reg. 56/2009 - Law 4/2009

Source: PwC, 2012

Under the previous Contract of Work (CoW) system (now replaced by a new licensing system under the 2009 Mining Law), there were obligations for mining companies to grant use of use of mineral infrastructure to the public (PWC, 2012). Moreover, many companies develop both social and physical infrastructure that can be used by communities as part of their CSR programs (Devi and Prayogo, 2013).

2.5 Key Respondents' Perceptions Of Current Challenges In The Implementation Of Spatial Planning

In Indonesia, spatial plans (*Rencana Tata Ruang Wilayah*) are the key mechanisms employed to manage development activities including mining and major infrastructure development. A national respondent responsible for spatial planning stated that "spatial planning is the frontline of how to better control the use of all land and water, including mining and transportation corridors" (gathered during the field work in October 2014). This intended goal however is not necessarily being achieved due to lack of horizontal/vertical coordination as well as uncertainties in the implementation stage of the spatial plans and limited government regulatory power as described in this section.

2.5.1 Limited Vertical And Horizontal Government Coordination

Horizontal coordination

The majority of government interviewees in both case study regions recognised that there are coordination issues between different government departments and agencies at all government levels. Historically, development activities in Indonesia were sectoral based which meant that each department and ministry had their own plans and maps. The former spatial plan law was regarded as ineffective to assist the integration of sectoral developmental plan. Conflicts often occurred due to inconsistencies between what is designated under the National Spatial Plan and what is assigned under the Ministerial Decree.

Under the new Indonesian spatial planning law No. 26/2007 there has not been enough emphasis on the harmonisation of different departments and inter-departmental coordination is still lacking. The law provides enough power to 'manage' lands but limited power to 'regulate and enforce' the agreed spatial plan. Further, a National Government respondent said that while there are a number of ad-hoc institutions or boards that also try to assist with coordination (e.g. *Badan Koordinasi Penataan Ruang Nasional* (BKPRN); *Badan Koordinasi Penataan Ruang Daerah* (BKPRD)), these bodies are usually just coordinating forums and do not have a lot of regulatory power to ensure coordination.

This concern was echoed at the Southeast Sulawesi Provincial Government Workshop in October 2014. The majority of sub national government respondents in this region highlighted that there was a lack of coordination between sectoral agencies and different levels of governments at provincial and regency/city levels. For example, the one of regency government respondents noted that their "coordination body has never met before this and that there are many conflicts between agencies and high staff turnover/movement." Further even in regions where coordination was not seen as a particularly big issue, it was still noted that improvements needed to be made in terms of the frequency of meetings and communication between agencies.

Vertical coordination

A national respondent responsible for the national spatial planning said that all sub-national Spatial Plans should be complementary of national interests as all sub-national plans technically need to be approved by the Directorate General of Spatial Planning under the Minister for Public Works before being regulated as a statutory document by the local law. However in practice there seem to be some differences between national and sub-national planning. Some regency government respondents suggested that there is disconnect between national, provincial and regency government spatial plans as each level of government has their own individual visions and plans for a particular region, which do not always match. Currently one regency government is in contest with the National Government about the latest National Spatial Plan and its designated land use areas. Under the new plan, a larger area of land is designated as National Park than the previous plan. This has implications for the regency government as they are unable to issue developments for land classified as National Parks without approval from the Ministry of Forestry. Currently, the regency government is using the approved Spatial Plan from 1999.

Lack of both horizontal and vertical coordination was raised as a problem in discussions about the development of mineral infrastructure, in particular for port development. For instance, a provincial government respondent during the Southeast Sulawesi government workshop suggested that there is little control from the provincial government on how ports associated with mining are planned and developed (see Figure 2.6). Respondents referred to the Ministry of Transportation as the institution that is responsible for the port development. During the last visit however, the research team was unable to secure an interview with this institution.

2.5.2 Implementation Issues

National, provincial and regency governments all noted issues associated with implementing planning mechanisms in practice. Many of the government respondents interviewed commented that while planning mechanisms (e.g. Spatial Plans) are developed and "look good on paper", there are often issues surrounding the implementation of such plans. One participant from the regency government who attended the workshop stated "we [government] have lots of spatial planning laws and books, but they are not implemented well...this is a problem in all of Indonesia." Overall, there seems to be a disconnect between theoretical planning and what is happening on the ground.

Furthermore, almost all respondents suggested that land allocations and permits for developments are influenced by political agendas and vested interests which sometimes caused difficulties in implementing the spatial plan. When further examples were asked, respondents were hesitant to provide further details.

2.5.3 Limited Government Regulatory Power

In 2001, Indonesia implemented the Law on Regional Autonomy (Law 22/1999 revised by Law 32/2004). The regional autonomy law essentially transferred national government authorities to sub-national governments in all government administrative sectors, except for security and defence, foreign policy, monetary and fiscal matters, justice, and religious affairs. [9] Consequently, spatial planning activities and responsibilities were handed over to the sub-national level, in particular regency and city governments.

Multiple government participants from both case study regions noted that sub-national governments experience some difficulties with stopping illegal developments (e.g. residents building on government land, illegal quarrying, etc.). One participant from the Sangatta Regency Government workshop said that there is often a community mindset that "if they own the land they can build anything" despite what the area Spatial Plan stipulates.

Under the regional autonomy law, provincial governments do not have the regulatory power to stop illegal developments. However, one respondent from provincial government said that while regency and city governments may have the regulatory power, they often lack the confidence to direct the community and stop illegal developments. Consequently, there is limited government supervision and management of developments that aren't in line with the government's Spatial Plan.

Recently, there has been a new initiative introduced across Indonesia to produce '*Penyidik Pegawai Negeri Sipil Penataan Ruang*' (inspector for spatial planning) as mandated by the Public Works Ministerial Regulation 13/PRT/M/2009. The inspector is given a special power (similar to the power of Police) to conduct a case investigation in relation to illegal land encroachment and development.

[9] The issuance of new regional development law (23/2014) may change the landscape of decentralisation practices in Indonesia whereby the power of decentralisation has been transferred from the regency government to provincial government.

CHAPTER 3: SOCIO-ECOLOGICAL FACTORS FOR THE MINERAL INFRASTRUCTURE PLANNING

3.1 SUMMARY

This chapter answers one of the research questions: "*what are the key factors that need to be included in promoting sustainable infrastructure development associated with mining industries?*" In answering this question, we applied a series of filtering methods in order to:

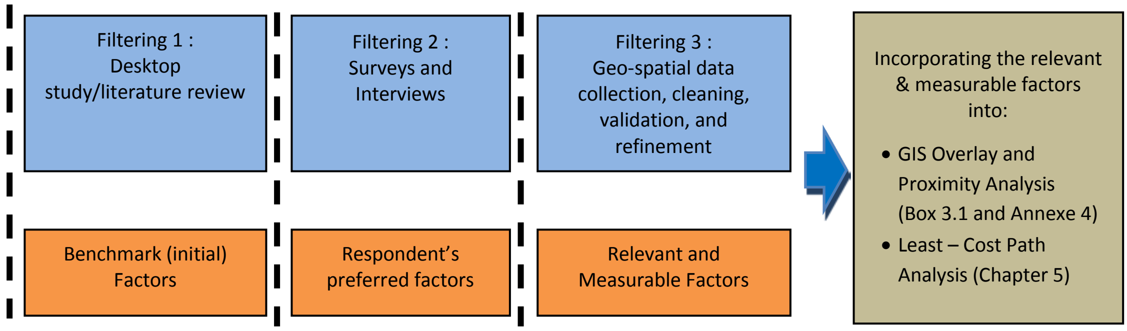
- benchmark socio-ecological factors from the literature review
- understand how key stakeholders (government officials, representatives of mining companies and communities) ranked socio-ecological factors in order of importance
- define socio-ecological factors that are relevant, important and readily available in geo-spatial formats to be utilised in the GIS analysis of mineral road infrastructure (e.g. overlay and least-cost path methods).

Three filtering processes are discussed in this chapter to produce the available, relevant and measurable socio-ecological factors in the GIS format. Through these processes, our findings suggest a list of 13 socio-ecological sub-factors and the nine subsequent GIS layers (Table 3.3) that can be used for the GIS analysis and modelling.

3.2 METHODS

The research team applied three filtering methods to determine a list of the most important, appropriate and available socio-ecological factors to further develop our GIS tools in mineral infrastructure planning. Figure 3.1 identifies the three filtering methods that are discussed below in further detail.

Figure 3.1 Filtering methods



3.2.1 Filtering 1: Desktop Study/Literature Review

A desktop study and literature review was undertaken to identify the initial socio-ecological factors as the potential benchmarks of socio-ecological factors (as suggested in existing literature, including publicly available research reports, journal articles and case studies). In this process, an initial list of six broad socio-ecological factor categories with their key elements was developed (as shown in Table 3.**1**). These broad categories provided the benchmarks to proceed to the next filtering process. This process involved conducting surveys, in-depth interviews and field observations to contextualise the initial broad factors in the local case study contexts in East Kutai Regency and South Konawe Regency, as described in the Section 3.2.2.

Table 3.1 Initial socio-ecological factors for consideration

Social and Environmental Factors	Key elements to consider
Community	• Population settlements • Urban and commercial areas • Community livelihood source areas (e.g. agricultural land and activities, fishing, hunting etc.) • Social infrastructure (e.g. schools, hospital, community buildings etc.) • Tourism areas
Water issues	• Existing water bodies: o Rivers or streams o Wetlands o Lakes o Coastal zones o Floodplains o Ground water systems • Marine resources, species and habitats • Community wells
Flora, fauna and biodiversity	• National parks or protected areas (marine or terrestrial; e.g. forested areas) • Specific ecological zones/habitat types (e.g. Orang Utan habitat) • Areas of high biological diversity • Threatened or endangered species • Habitat corridors or linkages between areas of remnant vegetation
Topography, meteorological and geological issues	• Slope classification (i.e. slope gradient) • Soil classifications • Existing soil erosion areas • Specific climatic conditions

Social and Environmental Factors	Key elements to consider
Mineral deposits and existing infrastructure	• Operating mines and mines leases • Planning infrastructure corridors • Major and minor roads networks • Coastal port
Indigenous Peoples and cultural heritage	• Indigenous People populations (past and present) • Areas that support IPs livelihoods • Areas of IP cultural significance or purpose • Other non-Indigenous People heritage listed sites

Sources: ICMM (2006); ICMM (2010[a]); ICMM (2010[b]) and New South Wales Department of Urban Affairs and Planning (2000).

3.2.2 Filtering 2: Surveys And Interviews

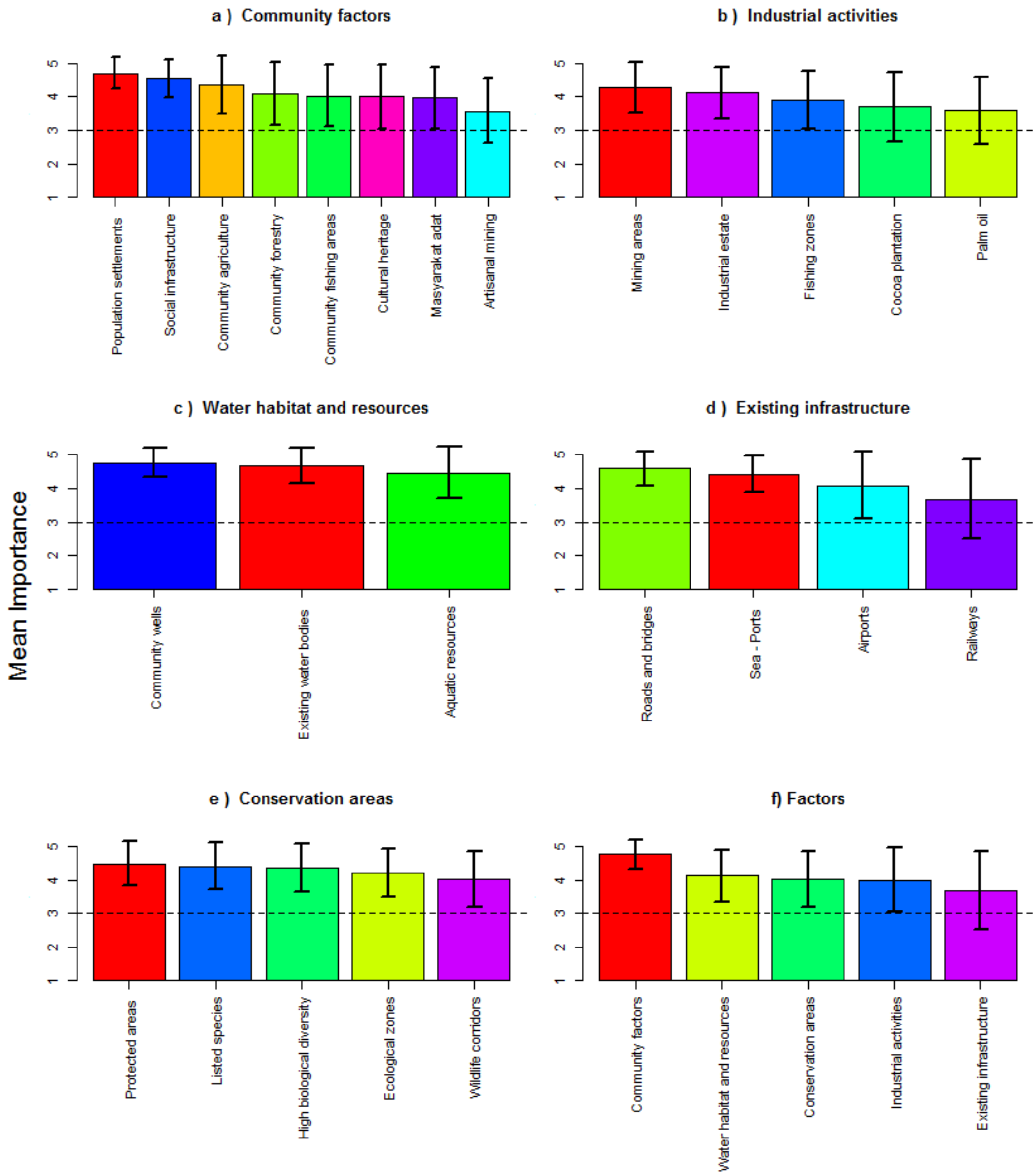
The second filtering process was aimed at validating and refining the initial (benchmark) factors through stakeholder engagement (in-depth one-on-one interviews; group discussions and workshops in October 2014) and quantitative weighting surveys (included Likert scales) to determine whether proposed socio-ecological factors are relevant and considered to be a priority in infrastructure planning. Subsequently, we transferred these initial factors and sub-factors into preferential survey statements (questionnaire) as provided in Annexe 3. In the survey questionnaire, we decided to include five factors and 25 sub-factors. We eliminated the specific factor of topography, meteorological and geological issues in the questionnaire as there are strong legal requirements that developments need to adhere to (e.g. slope suitability).

The research team conducted 37 interviews/social surveys across multiple stakeholder groups (National Government, Provincial Government, Regency Government, community representatives and companies) to determine the perceived importance of each sub-factor. The questionnaire included a Likert scale from 1 to 5[10] for each sub-factor and participants were asked to rate each based on their perceived degree of importance. The mean rating value was calculated for each sub-factor to determine the average response across all stakeholder groups. To determine each sub-factor's cost weighting for the GIS Sustainability Maps, each sub-factor's value was rescaled and weighted (see Chapter 5 for further details about rescaling and cost weighting process).

[10] 1 = "Extremely not important"; 2 = "Not important" 3 = "Neutral"; 4 = "Important"; and 5 = "Extremely important".

Analysis from all socio-ecological sub-factors across all stakeholder groups (Figure 3.2) found that the most important sub-factors were population settlements and existing water bodies. However, all mean responses were Neutral (3) or higher. Respondents rarely attributed any of the sub-factors as not important (e.g. “Extremely not important” (1) or “Not important” (2)) with only 40 negative responses out of the 893 total individual responses for all sub-factors.

Figure 3.2 **Factor and sub-factor mean value for all stakeholders. (a-e) Mean importance for each subfactor, (f) Mean responses for each factor category. Error bars represent the standard deviation of the responses. Dotted line represents a neutral response.**



In general, all stakeholder groups' responses were similar with some small differences between groups.

For the purpose of this project, the cost weighting of sub-factors was determined as an average across all stakeholder groups. However it is important to recognise that different stakeholder groups are likely to have different responses and attitudes to development, which may have implications during participatory infrastructure planning processes.

Once we contextualised the initial factors in both case study regions through these survey exercises, we then triangulated these factors with the data availability in GIS format as presented in the Section 3.2.3. Insights regarding the selected socio-ecological factors gathered through interviews are discussed further in Section 3.3.

3.2.3 Filtering 3: Geospatial Data Collection, Cleaning, Validation And Refinement

The third filtering process aimed at collecting, cleaning, validating and refining secondary GIS data to determine whether proposed GIS socio-ecological layers are realistic and measurable (i.e. there is available good quality and reliable data to measure the factor).

During the fieldtrips in October 2014 and March 2015, the research team also collected all available GIS data from government and company key informants in South Konawe Regency (Southeast Sulawesi) and East Kutai Regency (East Kalimantan Province). To clean, validate and refine the collected GIS data, the ITB and CSRM research team restructured and tabulated the collected data. Restructuring the data involved sorting, cleaning and classifying all available data in line with the identified sub-factors from the literature and stakeholder surveys. The results of available, relevant and measurable factors/sub-factors are presented in Table 3.2.

Table 3.2 Available, Relevant and Measureable socio-ecological factors and GIS layers

1. LITERATURE REVIEW		2. STAKEHOLDER SURVEYS	3. DATA COLLECTION & REFINEMENT	
Socio-ecological Factor Categories	**Sub-factors**	**Mean response (indicating relative importance of sub-factor)**	**Available GIS data layers**	**Notes / reasoning for lack of available GIS data**
Community factors	Population settlements	4.7	YES	
	Community agriculture	4.4	YES	
	Community forestry	4.1	YES	
	Community fishing areas	4.0	NO	Related agencies do not specify fishing areas nor have the map
	Artisanal mining	3.6	NO	We did not find any

1. LITERATURE REVIEW		2. STAKEHOLDER SURVEYS	3. DATA COLLECTION & REFINEMENT	
Socio-ecological Factor Categories	**Sub-factors**	**Mean response (indicating relative importance of sub-factor)**	**Available GIS data layers**	**Notes / reasoning for lack of available GIS data**
				documents containing information about artisanal mining
	Social infrastructure	4.6	NO	The maps are not complete. There are just several districts maps which contain information about social infrastructure
	Masyarakat adat	4.0	NO	There are no maps containing information about *masyarakat adat*
	Cultural heritage	4.0	NO	There are no maps containing information about cultural heritage
Water habitat and resources	Existing water bodies	4.7	YES	
	Aquatic resources	4.5	NO	There are no other aquatic resource maps
	Community wells	4.8	NO	There are no community wells maps
Conservation areas	Protected areas	4.5	YES	
	Ecological areas	4.2	NO	There are no maps containing information about ecological areas
	High biological diversity	4.4	NO	There are no maps containing information about high biological diversity
	Listed threatened and endangered species	4.4	NO	There are no maps containing information about listed species
	Wildlife corridors	4.0	NO	There are no maps containing information about wildlife corridors
Industrial activities	Mining areas	4.3	YES	
	Palm oil	3.6	NO	There are no maps containing information about palm oil
	Plantation	3.7	YES	Only general plantation data available

1. LITERATURE REVIEW		2. STAKEHOLDER SURVEYS	3. DATA COLLECTION & REFINEMENT	
Socio-ecological Factor Categories	**Sub-factors**	**Mean response (indicating relative importance of sub-factor)**	**Available GIS data layers**	**Notes / reasoning for lack of available GIS data**
	Fishing zones	3.9	NO	There are no maps containing information about fishing zones
	Industrial estate	4.1	NO	There are no maps containing information about industrial estates
Existing infrastructure	Sea ports	4.4	NO	Map with "shp format" not available
	Roads and bridges	4.6	YES	
	Airports	4.1	NO	Map with "shp format" not available
	Railways	3.7	NO	There are no existing railways

From these three filtering processes described above, a list of 13 sub-factors and 9 subsequent socio-ecological GIS layers (Table 3.3) were identified. These layers were assessed as being 'relevant measurable and available', and could be utilised in our GIS methods, which included: evaluative overlay and proximity analysis in East Kutai Regency (Annexe 4); and progressive mineral infrastructure planning in South Konawe Regency using least-cost path analysis (Chapter 5). The next section provides further discussion about the chosen GIS layers based interviews and meetings with key respondents in both case study regions.

Table 3.3 GIS socio-ecological layers for Southeast Sulawesi

Sub-factor	*GIS data layer*
1. Population settlements	*Population settlements*
2. Community agriculture	*Community agriculture*
3. Existing water bodies 4. Aquatic resources	*Water bodies*
5. Protected areas 6. Ecological areas 7. High biological diversity 8. Listed species	*Protected areas*
9. Mining areas	*Mining permit*
10. Cocoa plantations	*Plantation crops*
11. Sea ports	*Ports*
12. Roads	*Roads*
13. Airports	*Airport*

3.3 Contextualising The Chosen Socio-Ecological GIS Layers Based On Key Respondents' Responses

During our fieldwork in October 2014, the research team also conducted one-on-one in-depth interviews, focus groups and workshops. Findings from these meetings are described below to further contextualise the available, relevant and measureable socio-ecological factors for mineral infrastructure planning.

3.3.1 Population Settlements

In smaller less developed parts of Indonesia, many communities are isolated due to fragmented and poorly maintained infrastructure. If properly developed, infrastructure can provide vital economic links and opportunities for isolated communities across Indonesia. Improved links with economic markets and commercial and industrial activities can improve individuals' access to employment opportunities and increase household incomes. However if not planned properly, infrastructure developments can have severe environmental, social and health impacts on surrounding communities and can disrupt and alter their current livelihood strategies.

Most respondents from the stakeholder surveys believed that infrastructure such as roads and ports provide positive benefits to communities as they help open up remote locations and support the local economy. Therefore, if properly managed and planned, population settlements have a high preference for infrastructure developments. In urbanised areas however, key respondents suggested that industrial activities should not use public roads due to the negative impacts that can result, such as heavy traffic, accidents, degrading the quality of roads and dust.

The settlement GIS layers were not specifically available so we derived the settlement GIS data from the available land-use GIS layer, though the data attributes are mostly incomplete. For this reason, the research team is aware for the potential of inaccuracy of our settlement data. For future research, this layer can be further improved to support better GIS analysis.

3.3.2 Community AGRICULTURE

Community agricultural land and activities provide a vital livelihood source for many rural communities across Indonesia. Infrastructure developments and corridors often require a significant parcel of land, which can pose a threat to designated community agricultural land. However if planned appropriately infrastructure developments can provide important links to economic markets and improve productivity.

Most respondents from the stakeholder surveys agreed that infrastructure projects (particularly roads and ports) help connect local economic activities (including community agriculture) and support the local economy. Consequently, our respondents had a high preference for road and port developments to be located near to community agricultural areas. For future mineral infrastructure planning however, this statement needs to be confirmed with communities (farmers) that may be impacted by road and port development. The potential impacts of any development need to be discussed with the impacted communities and they should be given a space to voice their concerns through proper community engagement. To help this exercise, we provide guidance for community engagement in Chapter 4 of this report.

Similar to population settlement, the community agriculture data was obtained from the land use GIS data. The land use GIS data are selected and then extracted to get the community agriculture area. The community agriculture data used in this research is a combination of data for dry and irrigated agriculture.

3.3.3 Water Bodies

Existing water bodies include both freshwater sources (rivers, creeks and lakes) and marine water sources. Infrastructure projects are likely to have significant detrimental impacts on existing water bodies. Large-scale infrastructure developments can alter and divert existing waterway systems and catchments. Infrastructure developments can also affect water quality due to the increased risk of soil erosion, runoff of sedimentation and discharge of pollutants. These impacts can significantly affect the surrounding wildlife and communities who rely on the water sources to sustain their livelihoods.

In addition, flood prone areas were identified as a very important issue for the majority of survey respondents. During Indonesia's rainy season, high rainfall combined with poor planning, deforestation and clogged waterways can lead to large-scale flooding. It is therefore important that future infrastructure planning aims to avoid flood prone areas and adopts flood mitigation measures to reduce flood risks. Consequently, all existing water bodies have a low preference for infrastructure developments and it is suggested that mineral infrastructure planning should minimise (or preferably avoid) the destruction of water bodies.

For our GIS analysis as described in Chapter 5 and Annexe 4, the river GIS layer is available and we extracted the data of existing water bodies from this layer. This available layer was obtained from the regional planning office as basic physical data, and we used a buffer area of 25 metres from the river to derive our existing water bodies data.

3.3.4 Protected Areas

Indonesia is home to an abundant, diverse, and unique array of ecosystems and rural community livelihoods. Large-scale infrastructure projects pose a significant threat to Indonesia's national parks, biodiversity and ecosystem services. Specifically, infrastructure projects can encroach on protected lands, remove and degrade valuable vegetation and habitats, and fragment ecosystems and animal migration routes. New transport routes can also open up previously remote biodiversity regions and place them at risk of further development and degradation. Vehicle, sea and rail traffic also pose a direct threat to the health of terrestrial and marine wildlife.

Indonesia's national parks and protected areas are already vulnerable from the encroachment of illegal development, logging and other industries. Therefore, national parks and protected areas have a low preference for infrastructure developments and any future mineral infrastructure development should minimise and, ideally avoid further destruction of protected areas.

The protected areas GIS data were obtained from available land cover data, however, the land cover data had to be extracted first to enable access to the protected areas data. For the national parks, the area was obtained from National Park boundaries data from the regional planning office.

3.3.5 Mining Permits

Across Indonesia mining sites require a range of infrastructure to support their mine operations and value chains, including roads, railway, seaports and other processing industries. The construction and maintenance of such developments is costly and requires a considerable investment of capital and other resources from individual companies.

The infrastructure developments can also have a range of negative social and environmental impacts on their surrounding environment. When multiple mines operate in a particular area, these mine-supporting infrastructure networks can be extensive and their impacts wide ranging.

Shared and co-located infrastructure across multiple mine operations should be encouraged to minimise costs, improve efficiencies, and minimise the extent of infrastructure networks and their potential social and environmental impacts. The majority of stakeholders we surveyed expressed a high preference for infrastructure development to be located near to mines and mine leases.

Data and information about mining permits are available from the office of Energy and Mineral Resources. However, during our research, we found there was heightened sensitivity concerning the release of this type of data due to issues such as overlapping mining leases and un-clear boundaries of the leases. We obtained the mining lease data from various offices and they were shown to be inconsistent. The research team undertook a comparison of several maps and carried out ground-checking through the use of Google Maps, especially in relation to the existing mining leases.

3.3.6 Plantation Crops (Cocoa)

Indonesia is the second largest producer of cocoa in the world. A range of infrastructure is required to support the export of cocoa. Often companies will either develop their own infrastructure or utilise existing infrastructure to export their goods. This either places added stress on existing infrastructure, or can be costly for companies and have a range of negative social and environmental impacts. Stakeholders expressed a high preference for infrastructure developments to be located near cocoa plantations.

Although specific GIS data on cocoa plantations is not available, it would be included within the plantation GIS data, which is available. This plantation GIS data can be obtained from the regional planning office.

3.3.7 Sea Ports, Roads And Airports

In the extractive industries, ports, roads and railways are required to either export mineral products or service gas developments. Across Indonesia, many extractive industry companies have developed ports, roads and sometimes railways for the sole purpose of exporting their own materials. This means that in many Indonesian mining regions, multiple ports and roads are developed in close proximity to each other and without consideration of existing infrastructure developments within that region. This lack of coordination leads to high costs, inefficiencies, extensive infrastructure networks and often wide-ranging negative social and environmental impacts.

To limit the extent of these unplanned networks, their impact on the surrounding environment and required company capital and resources, multi-user infrastructure developments should be encouraged. Consequently existing ports, roads and railways have a high preference for future infrastructure developments, meaning that planning should ensure that future infrastructure is co-located with the existing infrastructure.

GIS data for existing infrastructure can be obtained from the regional planning office. Road data contains information about types of roads, which include national roads, provincial roads, and regency roads.

3.4 Utilising the available, relevant and measurable GIS layers into GIS analysis and modelling specific to this research

The available, relevant and measurable GIS layers that were produced through the three filtering processes are used in our GIS analysis and modelling, that is discussed in detail in Annexe 4 for the GIS proximity analysis and Chapter 5 for integrated mineral infrastructure planning using the least-cost path analysis.[11]

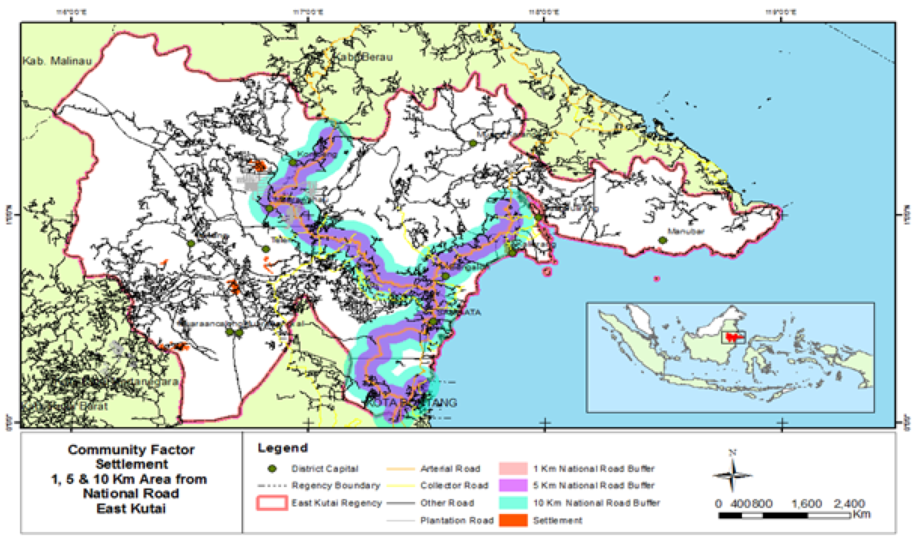
We applied a GIS proximity analysis to evaluate the relationship between road infrastructure and the socio-ecological GIS layers using East Kutai as an example. A summary of the GIS proximity analysis is provided in the Box 3.1 below.

[11] Annexe 4, meanwhile, describes a suitability and proximity analysis of the existing road networks and the current landscape of the region limited to these selected factors. The suitability analysis was applied to the brown-field mining areas of East Kutai Regency (East Kalimantan Province).

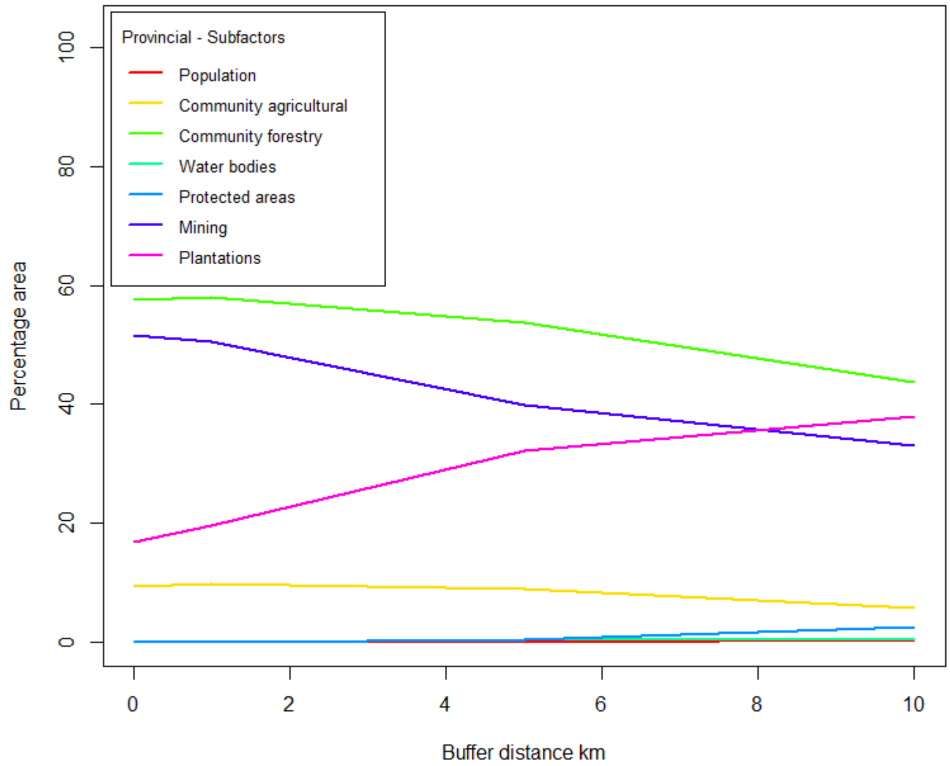
Box 3. 1 GIS Proximity Analysis Example

The proximity analysis characterises the tendency for a road to be located closer or further away from land cover representing a social-ecological factor. It is useful to characterise how development has proceeded in a region and to contrast the preferences described by the respondents to what actually has occurred. For example, the respondents suggested that conservation areas and road infrastructure are incompatible. However, if the proximity analysis finds that conservation areas tended to occur closer to the roads rather than further away this would indicate that the historical planning of infrastructure is not in accordance with respondent preferences.

The image below shows each GIS layer representing a social-ecological factor buffer 1 km, 5 km and 10km from the existing national, provincial and regency road networks



The proximity analysis calculates the buffer distance versus the percentage area of the buffer occupied by a socio-economic factor. The following plot shows the output for provincial roads. The analysis indicates that Community Forestry is more likely to be found closer to the road than further away and plantations have an opposite trend. Meanwhile, population, protected areas, and water bodies have a very small area ~1 %.



Further outputs from this proximity analysis in East Kutai Regency can be found in Annexe 4.

Chapter 5 describes a progressive modelling of GIS least-cost decision support for linear mineral/mining infrastructure planning. The selected socio ecological factors will be further weighted to produce the high and low cost surface for the modelling. This modelling was applied to the green-field mining areas of South East Konawe Regency in Southeast Sulawesi Province.

Before describing this GIS modelling the next chapter (Chapter 4) describes the importance of stakeholder engagement in the mineral infrastructure planning process and methods that can be used to generate and refine data, as well as to generate different infrastructure planning scenarios that can be deliberated by stakeholders.

The urgent need for this engagement was mentioned by key stakeholders in both case studies who stated that stakeholder engagement at project level (e.g. AMDAL process) and regional strategic planning (e.g. spatial planning process) has been lacking. Despite relevant laws and policies that have promoted community participation and stakeholder engagement in regional planning and other project approval processes, there is limited guidance on how this should be implemented. Consequently, a framework for community engagement is proposed in Chapter 4. This is not intended to replace those legal requirements, rather it clarifies the procedures, techniques and aspects need to be considered in particular to promote participatory mineral infrastructure planning as an integral part of this research.

CHAPTER 4: A FRAMEWORK FOR COMMUNITY ENGAGEMENT IN MINERAL INFRASTRUCTURE PLANNING

4.1 SUMMARY

This chapter proposes a framework for engaging communities and other stakeholders throughout the mineral infrastructure planning process. Community engagement is an important part of infrastructure planning as it helps government and practitioners to tap into local knowledge and expertise, gain a wider range of perspectives, and build mutual acceptance of a particular project or intervention. Including stakeholders, particularly impacted communities, throughout the mineral infrastructure process will help:

- foster open dialogue and deliberation
- develop productive relationships
- enable stakeholders to work together to develop mutually agreed upon solutions
- create a sense of acceptance and ownership among stakeholders

While community participation is mandated in Indonesia through a number of provisions (environmental approval regulations (AMDAL), the Spatial Planning Law and the annual planning process (*musrenbang*), our research found that in practice community engagement is often a once off one-way activity with limited feedback and incorporation of community views. It is imperative that future mineral infrastructure planning aims to include inclusive and responsive engagement strategies to ensure that impacted community groups' perspectives and aspirations are considered in future infrastructure projects.

This chapter aims to assist land use planers to better incorporate community engagement into the mineral infrastructure planning process. It proposes an engagement framework and outlines a number of engagement techniques that may be applied to engage communities and other relevant stakeholders throughout a participatory GIS infrastructure planning activity.

It is important to note that not all engagement techniques are the same or have the same outcomes. Therefore it is essential that those who are involved in land use and/or mineral infrastructure planning carefully plan for and consider the most appropriate technique/s prior to starting any participatory infrastructure planning processes. This chapter intends to assist government to do this.

4.2 IDENTIFYING CONTEXTUAL ISSUES

It is imperative that governments consider the context in which they aim to undertake the mineral infrastructure planning process as this can have implications on the outcome of the process. For example, government will need to consider the political environment and available resources and support as this may influence decision-making and uptake. Governments will also need to consider the particular stakeholder group's characteristics, background and available resources as this will affect how they understand and connect with them (Table 4.1).

Table 4.1 Contextual considerations

Political and governmental contextual considerations	
Political environment	The level of political support or awareness
Legislative environment	The legal requirements for community participation
Policy and planning cycles	Understanding how community engagements fits within the broader infrastructure planning process
Resources	Available resources to support engagement activities (skills, resources, time, budget etc.)
Stakeholder characteristics and features	
Stakeholder groups	The different stakeholder groups
Nature of impact and stakeholder interest	Each stakeholder group's impact from, or interest in, the mineral infrastructure project
Demographic features	The characteristics of the stakeholders (age, gender, ethnicity, socioeconomic mix, existing infrastructure, types of industries etc.)
Preference for engagement	The stakeholder group's preferred level and style of engagement
Previous engagement experience	Previous experience (positive and negative) with government-led engagement practices
Existing engagement structures and/or processes	Identify and acknowledge any existing engagement structures or processes that are practised, particularly within a community.

4.3 ENGAGEMENT STRATEGIES FOR GIS-SUPPORTED MINERAL INFRASTRUCTURE PLANNING

The GIS-based approach to mineral infrastructure planning proposed in this project requires four stages of stakeholder engagement:

1. Engaging to identify current and future infrastructure needs (Section 4.3.1)

2. Engaging to identify and select socio-ecological factors to be used in the GIS tool (Section 4.3.2)

3. Engaging to ground truth and collect community-generated data (Section 4.3.3)

4. Engaging to map scenarios for infrastructure corridor development (Section 4.3.4).

The stakeholders who should be involved in the above engagement activities will depend on the local and regional context, as well as the stage of engagement, however they may include:

- Provincial and regency government officials who are involved in infrastructure planning and economic development planning, including planning mineral development
- Industry bodies and mineral resource companies with operations and interests in the region
- Potentially impacted communities
- Civil society groups (CSOs)

In this research project, the four stages of engagement described above form part of a broader participatory GIS process. Participatory GIS involves practitioners engaging with local communities and other stakeholders to enable them to communicate spatial information about particular aspects of their communities (e.g. cultural resources, land tenure systems etc.) in order to influence planning processes and policies (IFAD, 2009). It includes enabling local communities to actively participate in the generation and mapping of data.

The four stages of stakeholder engagement are summarised in Table 4.2 below. Each stage of engagement has specific aims, categories of stakeholders who should be engaged, and recommended engagement techniques. Each stage forms a critical component of the infrastructure corridor planning process.

Table 4.2 The Four Stages of Stakeholder Engagement

Stage	Aim	Targeted stakeholder group/s	Planning level	Engagement technique
<u>Stage one:</u> Identify current and future infrastructure needs	Identify all points (mineral leases and existing infrastructure) that may need to be connected by the proposed mineral infrastructure corridor or network	Provincial and Regency Government; Mineral companies and industry bodies; Potentially impacted communities.	Strategic	Reference Group
<u>Stage two:</u> Select	Identify, refine and weight the	Provincial and Regency	Regional	Quantitative survey, Multi-

Stage	Aim	Targeted stakeholder group/s	Planning level	Engagement technique
appropriate socio-ecological factors for the planning process	importance of socio-ecological factors to be used in the GIS mapping tool.	Government; Communities; Mineral companies; NGOs.		stakeholder forum,
<u>Stage three:</u> Ground truth and collect community-level data	Collect data from communities and other local stakeholders to fill gaps in missing data. Ground truth and verify previously collected data.	Communities, NGOs	Project	Community discussion groups/ workshops, One-on-one interviews,
<u>Four:</u> Map scenarios for infrastructure corridor development	Provide input into alternative mineral infrastructure corridor or network maps.	Provincial and Regency Government; Communities; Mineral companies; NGOs.	Regional	Design workshop

It is suggested that the entire engagement process discussed in the sections that follow can be overseen by a specific Mineral Infrastructure Planning Committee – within the responsible government agency e.g. regional planning office.

4.3.1 Engagement To Identify Current And Future Mineral Infrastructure Needs

The first stage of engagement involves consulting with key stakeholders to identify current, planned and potential infrastructure, including mineral infrastructure, in a region. One mechanism used to obtain such information is through formation of a reference group. Reference groups are usually comprised of a number of invited representatives who have a particular interest in a given topic or project. Such groups meet regularly to provide high-level oversight of the direction, implementation and evaluation of a particular project or intervention.

In the case of mineral infrastructure planning, reference group members may include representatives from national, provincial and regency government agencies, and other key strategic stakeholders in the region, including from industry. It is important that participants in the reference group bring substantial knowledge and expertise in the areas of mineral development and planning processes, so that they are able to help:

- identify all required GIS points (mineral leases and existing infrastructure) that might need be connected through the mineral infrastructure planning networks or corridors.
- identify future infrastructure that might be needed in the event that known mineral deposits are developed
- provide ongoing perspectives, feedback and input into all aspects of the planning process

It is expected that the reference group would work collaboratively with the Mineral Infrastructure Planning Committee described earlier.

4.3.2 Engagement To Select Appropriate Socio-Ecological Factors For The Planning Process

The second stage of stakeholder engagement supports the process of selecting the socio-ecological factors outlined in Chapter 3. As discussed in section 3.2.1, once desktop research has identified a preliminary list of socio-ecological factors, planners should engage with a range of stakeholders to refine and weight them according to their perceived importance. Two engagement techniques can be employed to do this: 1) qualitative surveys; and 2) multi-stakeholder forums.

Careful stakeholder identification and mapping is a critical step that must be taken prior to applying these engagement techniques. This is because different stakeholders will likely suggest factors that reflect their own particular preferences and agendas. There is nothing inherently wrong with this, but a failure to engage in a representative, inclusive manner with all key stakeholders who are involved with, or have an interest in, mineral infrastructure planning is likely to result in a list of factors that may not align with the values of social and environmental protection, and may even lead to future conflict.

There are several useful stakeholder engagement guides providing practical guidance on how to ensure engagement is representative and inclusive. It is important to recognise that traditional stakeholder mapping techniques which prioritise stakeholders with high power and high influence over a project are not sufficient for identifying key stakeholders to the planning process. This is because local communities, irrespective of their capacity to influence a project, must also be able to provide input into the planning process.

The stakeholder identification and mapping process should yield a diverse list of stakeholders from the following groups:

- National, regional, and local government agencies involved or with an interest in infrastructure development
- Industry, including industry associations and mineral resource companies with operations or interest in the region.

- Civil society and community, including marginalised groups, youths and women's respresentatives.

Quantitative Surveys

Once stakeholders have been identified, quantitative surveys can be undertaken and multi-stakeholder forums held in order to refine and weight the socio-ecological factors. Quantitative surveys pose a standard set of closed ended questions to participants from a range of stakeholder groups to collect quantitative data and gain feedback on particular issues. Surveys may be conducted in person, over the phone, via the mail or electronically.

In this research project, quantitative surveys have been utilised to identify, validate and weight predefined socio-ecological factors to be included in the GIS planning process. The surveys included a weighted questionnaire (Likert scale) for each GIS factor to determine the 'cost weighting', which reflected stakeholders' perceptions about the importance of each identified socio-ecological factor.

Multi-Stakeholder Forums

This stage of the engagement also involves holding multi-stakeholder forums. There are two main aims of the multi-stakeholder forums. The first is to debate and validate the findings of the quantitative surveys, with the objective of deciding factor weightings, specifically to decide how important one socio-ecological factor is relative to another. The second aim is to use the workshops as a forum to assess the availability and quality of GIS data for each of the socio-ecological factors identified. While some data layers will be easy to find (e.g. for water bodies, national parks), other data layers may not exist (e.g. location of culturally or spiritually significant sites).

Exactly how many workshops need to be held will depend on each context. Ideally, these workshops should be run by an experienced independent facilitator. At the end of the workshops there should be a list of socio-ecological factors, each of which has been assigned a 'weight' representing their importance to mineral infrastructure planning, as perceived by the stakeholders. There will also likely be a list of socio-ecological factors for which data does not exist; this will also be weighted and ranked on importance. The reference group should also be a part of the multi-stakeholder forums, preferably as the initiator and organiser.

4.3.3 Engagement To Ground Truth And Collect Community-Level Data

A third stage of engagement involves engaging with local community groups to ground-truth data collected so far, and to generate new data for use in the GIS tool (i.e. to create new data layers). 'Ground-truthing' involves verifying the accuracy of GIS data or other information in the field through observation and / or engagement (Vajjhala, 2006). These engagement activities, which are an important part of the participatory GIS process, involve community mapping, whereby data collected by local communities is used to create digital data layers which can be used in GIS applications to undertake spatial analysis.

Engaging communities to ground-truth existing data, and to generate new data, is essential for a number of reasons: for one, it enables data and information produced by third parties (such as government agencies) about a particular region to be cross-checked with the people that actually live there. For example, data about forest cover obtained from official sources may be very different from local conditions, which is a common problem in Indonesia. Engagement therefore provides one way in which such data can be verified.

A second reason is that it enables local people who may be impacted by mineral infrastructure development to provide information to planners on factors that are important to them. For example, indigenous peoples in a mineral region can provide information about their areas of cultural or spiritual significance and traditional hunting grounds. In many parts of Indonesia, accurate geographic information about such things is very hard to find, let alone accurate geospatial data which can be used to create layers for a GIS tool. As a result, community participation in data generation enables some of the gaps in GIS data to be filled. This includes generating data on economic activities that may be important to local communities (e.g. customary *adat* forests). Some techniques for engaging communities to ground truth and generate data are described in the sections below.

Participatory Mapping Exercises

Participatory mapping is process by which communities are able to document their knowledge, ideas and rights by participating in the creation of maps (IFAD, 2009). Participatory mapping has become increasingly common in many parts of the world, particularly in developing countries where indigenous peoples and local communities are reliant on natural resources for their livelihoods, and want to protect their access, use and ownership rights, which are often governed by customary institutions and laws such as *adat* in Indonesia. Such rights are often legally insecure and community mapping has the potential to strengthen such rights in an effort to resist external claims or legal appropriation by state authorities (Peluso, 1995).

Participatory mapping is known by a variety of names including community mapping, counter mapping and indigenous mapping (IFAD, 2009). While there are differences in the specific techniques used, the basic approach is the same. It involves groups of non-experts who have a common interest participating in a map-making process. Participatory maps can present a wide range of spatial information at various scales. This can include layouts of villages, location and boundaries of customary forests, location of sacred sites and significant cultural areas, territories of indigenous peoples and so on. Participatory mapping can also map non-geographic information, such as characteristics of populations living in a particular area, health patterns and economic conditions. Once communities have participated in the generation of information through mapping, GIS officers can use this to generate spatial data layers, using GIS.

Participatory mapping in the context of mineral infrastructure planning presents significant challenges for those coordinating the participatory GIS process. Some of the most significant challenges include:

- Deciding which communities should participate in the mapping exercise.
- Deciding who from within those communities should participate. This decision requires addressing questions of geography, inclusivity and representation. How, for example, do planners ensure that all groups within a community, such as marginalised and vulnerable groups, get a chance to participate?
- Dealing with conflict between different communities and groups, for example over control over land and resources.
- How to resource the participatory process – participatory mapping is often a costly and time consuming process.
- How to ensure communities have the capacity to participate in community mapping exercises
- How to build trust with the communities who will be involved in mapping
- Deciding on who owns the data generated through participatory mapping and how it is used.

Many of these challenges are common to all stakeholder engagement processes and require solutions tailored to the specific context. There are a number of useful stakeholder engagement guides planners can refer to in order to design strategies for dealing with such challenges.[12]

Community mapping commonly takes place during workshops and working groups organised by planners / GIS officers in central locations such as sub-district and village offices. There is an emerging literature on participatory GIS, including in the context of indigenous communities in developing countries, which can be referred to when selecting specific techniques and methods that can be used to undertaken participatory GIS (e.g. see Ramierez-Gomez et al., 2013).

4.3.4 Engaging To Map And Debate Scenarios For Infrastructure Corridor Development

The fourth and final stage of engagement involves holding multi-stakeholder planning workshops in order to assess the pros and cons of different infrastructure corridor/network scenarios developed based on the socio-ecological factors identified through the research and engagement process. The idea is that the different scenarios, which actually represent linear paths and networks of infrastructure, would be graphically represented on maps. These maps can be created in real time using GIS software, thereby allowing stakeholders to visualise different planning scenarios in a short period of time. This enables infrastructure corridors / networks to be identified and adjusted based on input from the multi-stakeholder group during the workshop. It involves participants in the workshop comparing and debating different corridor / network scenarios. For example, in one scenario high value conservation forest and community *adat* land may have a strong influence on the geographic location of the

[12] See for example the forthcoming OCED *Due Diligence Guidance for Meaningful Stakeholder Engagement in the Extractives Sector* produced by the OECD and the Centre for Social Responsibility in Mining (CSRM).

corridor / network; in another scenario, the corridor might minimally encroach on a community *adat* forest, but has the advantage dramatically reducing the distance between a mineral deposit and a port (i.e. between 'nodes').

This stage of the engagement also provides an opportunity to verify that the GIS data used to develop scenarios accurately reflects their understanding of the socio-ecological factors that have been mapped. For example, indigenous groups may discover that the boundaries of their indigenous territories as depicted on a map are inaccurate. The workshop therefore provides an opportunity for such issues to be addressed.

Another important benefit of the scenario planning workshop is that it allows adjustments to be made that maximise potential economic opportunities that could be provided by the corridor but which may not normally be realised. For example, the location of the corridor might be adjusted so that it can connect with minor roads that service community plantations, thereby improving connectivity and links with broader markets.

As with any multi-stakeholder process there are a number of challenges and issues that will be encountered, such as:

- Failure to reach agreement on the location of the corridor / network
- Limited capacity of those in the working group to participate or fully understand the scenario development process
- Ensuring the most appropriate people are in the multi-stakeholder group (e.g. those who make decisions on spatial planning matters)
- Ensuring that representatives of the communities truly represent the interests of all potentially impact communities.
- Finally, given the diverse agendas of different stakeholder groups in the workshop it is critical that the process is led by an experience facilitator who can help the group achieve consensus and that the final scenario selected balances the interests of all stakeholders.

CHAPTER 5: GIS LEAST-COST DECISION SUPPORT FOR LINEAR MINING INFRASTRUCTURE PLANNING

5.1 SUMMARY

In this chapter a method for conducting GIS least-cost path analysis for linear mining infrastructure is described. Least-cost path analysis identifies optimal pathways between two locations as a property of the cost of traveling through different land use/cover types. The method entailed using the stakeholder interview data (Chapter 3) describing social and environmental factors that were identified as being important for infrastructure planning and characterising these in terms of orientation toward the compatibility of mining infrastructure. These environmental and social factors, characterised by spatial data layers, were then weighted according to infrastructure orientation.

A cost-surface was constructed by combining spatial layers for the social and environmental factors, where high cost locations represented areas where there was low preference (i.e. low suitability) for infrastructure. The cost-surface was used to identify areas in the least-cost path analysis that need to be avoided and areas that were compatible with linear infrastructure. For example, areas with high biodiversity conservation value would be avoided and populated areas that may benefit from linear infrastructure are preferred by the least-cost path analysis method. Our cost-surface also included a topographical layer which identified the suitability/cost of areas for infrastructure based on the slope of the topography (e.g. steep roads are difficult and costly to construct).

We used a South Konawe case study in South-East Sulawesi Province to demonstrate the application of the method identifying potential linear infrastructure networks for telecommunication, power lines and roads connecting mines, smelters, ports and power stations. Potential future scenarios included connecting existing locations and connecting future locations such as a planned electricity power station. We outline the spatial processing method and described the results of the scenario analysis in terms of locations that are suitable for linear infrastructure and identify an infrastructure network that has the least impact on social and environmental values. We also provide Python script for ArcGIS 10.x that automates the processing of the weighting, combining multiple spatial data inputs at any scale (see Annexe 5). We conclude by discussing the limitations of this approach.

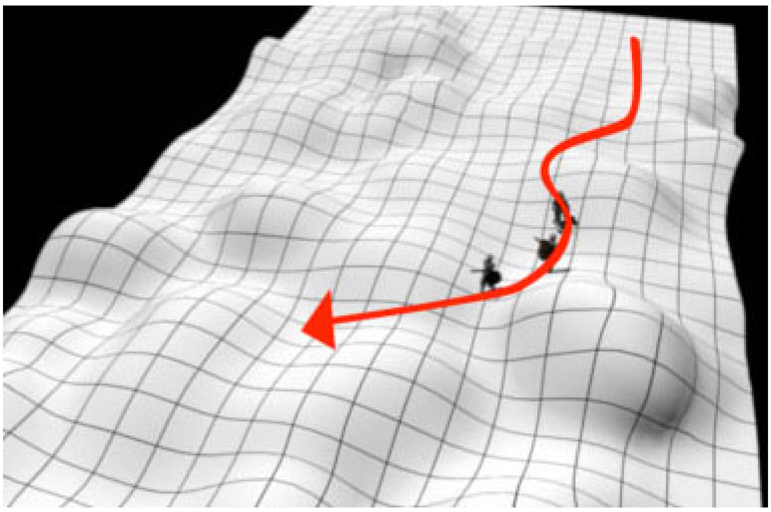
5.2 WHY DO WE SUGGEST LEAST-COST PATH ANALYSIS?

Regional planning approaches for mining aim to reduce the conflict associated with minerals/energy extraction and existing land uses such as forestry, agriculture and biodiversity conservation, whilst addressing the operational needs of mining. Achieving a balanced approach to planning requires that existing stakeholder preferences for specific land uses are incorporated. Regional land use planning approaches commonly utilise GIS to combine spatial data characterising the suitability of current and potential future development. While suitability mapping has been a core research and operational activity within geographic information sciences for many decades (Longley et al., 2011), the integration of spatially explicit socioeconomic data characterising land use values and stakeholder preferences with ecological data is a growing area of new research (Goodchild et al., 2000; Brown, 2012; Lechner et al., 2015).

An important consideration for developing a mine or multiple mines in a region is to optimally plan for linear mining infrastructure including roads, rails and power lines linking mines to electricity generators, processing (e.g. smelters) and transport facilities (e.g. ports). For linear infrastructure, least-cost path analysis has been used in GISs for planning a range of infrastructure including power lines (Bagli et al., 2011), transit corridors (Gahlot et al., 2012) and recreational trails (Sitzia et al., 2014). Least-cost path analysis identify optimal pathways between two locations as a property of the cost of traveling through different locations within an area. In a GIS, costs are represented by a raster (gridded spatial data) “cost-surface” (Figure 5.1). For example, train tracks need to be on relatively flat surfaces and thus a least-cost path analysis would identify a pathway that minimise the number of pixels with steep gradients. The cost surface can be a product of all the social, environmental, economic and engineering criteria that affect routeing.

A common method for integrating a range of stakeholder interests is through multi-criteria analysis (MCA) (Malczewski, 2006; Nyeko, 2012), which has been used with least-cost path analysis (Bagli et al., 2011; Grassi et al., 2014). MCA methods are used for structuring complex problems in order to explicitly consider multiple criteria used in the decision making process such as stakeholder land use preferences.

Figure 5.1 Least-cost pathway (red) and cost-surface (grid) where cost is represented by vertical height with raster spatial data (image from Wood et al. 2010).



There are numerous methods for mapping social data in order to characterise stakeholder interests for particular land use preferences (Lechner et al., 2014). These range from observed preferences (i.e. community/stakeholder preferences) derived from land use models (Goldberg et al., 2011), economic models (Polyakov et al., 2013) to self-reported preferences identified by social surveys using methods such as public participatory GIS (Brown, 2012) and finally to implicitly integrating social values using interactive GIS software (Lesslie, 2012). In the MCA literature commonly stakeholder representatives or experts weight spatial dataset based on their land use preferences (e.g. Bagli et al., 2011; Sitzia et al., 2014), while in this study we use quantitative social survey methods for identifying the orientation of stakeholders to infrastructure with existing land uses.

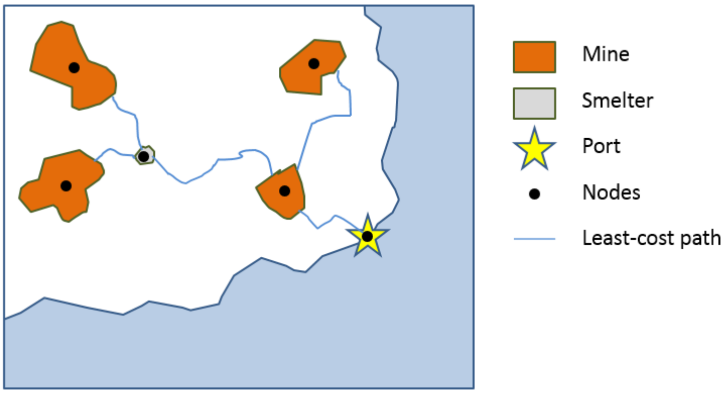
The aim of this chapter is to describe a method we developed for optimally planning linear infrastructure for mining regions that accounts for environmental and social factors. We build on existing research and describe a method involving use of a combination of structured interviews with stakeholders to identify environmental and social factors and social survey methods to identify weightings for a number of spatial data inputs (e.g. landuse, roads layer) in order to construct cost surfaces for the least-cost path analysis. We use a case study in Southeast Sulawesi to demonstrate the application of the method. We also provide Python script for ArcGIS 10.x that can be used by a GIS technician automates the processing of the weighting, combining multiple spatial data inputs at any scale. We conclude by discussing the limitations of this approach.

5.3 Methods

5.3.1 Least-Cost Paths Modelling Of Infrastructure Networks

We used least-cost paths and graph theory for modelling the optimal route of infrastructure at the regional scale. Using this method the landscape is simplified as nodes which represent the start and end points for least-cost paths. The start and end points for our study were mines and processing or transport facilities (Figure 5.2). A least-cost path is calculated using a raster cost-surface representing the orientation of stakeholders to infrastructure with existing land uses. Pathways between the start and end points which have the lowest accumulated cost are the least-cost path.

Figure 5.2 Using least-cost paths and graph theory a landscape is simplified as start and end points for least cost paths. The start and end points are mines and processing or transport facilities.



Where multiple nodes exist, multiple pathways can be identified to construct a network of pathways – an infrastructure network. We identified all least-cost paths between nodes in the landscape that did not go through an existing node. We also identified the minimum spanning tree which is the network with the smallest number of least-cost paths that connects all nodes.. This represents the smallest number of infrastructure links required to connect all nodes in the study area.

The cost-surface is a product of all the social, environmental, economic and engineering criteria that affect routeing identified with MCA. MCA techniques provide an explicit relative weighting system for the different criteria represented by our factors (Dodgson et al. 2009). In our study structured interviews were first used to identify key environmental and social factors (Table 5.1). These factors were considered as an orientation/preference for or against a specific kind of infrastructure development. The 5 major factors were divided into multiple sub-factors (see Chapter 3) and for each sub-factor available spatial data was used to construct the cost-surface. The factors were weighted equally for the analysis based on the desktop literature review and interviews which suggested that they are equally important.

Table 5.1 Factors and sub-factors used in the analysis

Factor	Subfactor	Spatial Data Present	Infrastructure orientation	Orientation weighted by number of subfactors	Orientation weighted by subfactors with available spatial data
A. Community factors	Population settlements	Y	88%	0.11	0.44
	Community agriculture	Y	74%	0.09	0.37
	Community forestry		64%	0.00	0.00
	Community fishing areas		61%	0.00	0.00
	Artisanal mining		-43%	0.00	0.00
	Social infrastructure		82%	0.00	0.00
	Masyarakat adat		-59%	0.00	0.00
	Cultural heritage		-60%	0.00	0.00

Factor	Subfactor	Spatial Data Present	Infrastructure orientation	Orientation weighted by number of subfactors	Orientation weighted by subfactors with available spatial data
B. Water habitat and resources	Existing water bodies	Y	-87%	-0.29	-0.44
	Aquatic resources	Y	-78%	-0.26	-0.39
	Community wells		-90%	0.00	0.00
C. Conservation areas	Protected areas	Y	-79%	-0.16	-0.20
	Ecological zones	Y	-68%	-0.14	-0.17
	High biological diversity	Y	-74%	-0.15	-0.19
	Listed species	Y	-76%	-0.15	-0.19
	Wildlife corridors		-61%	0.00	0.00
D. Industrial activities	Mining areas	Y	71%	0.14	0.24
	Palm oil	Y	44%	0.09	0.15
	Cocoa plantation	Y	48%	0.10	0.16
	Fishing zones		56%	0.00	0.00
	Industrial estate		65%	0.00	0.00
E. Existing infrastructure	Sea - Ports	Y	77%	0.26	0.26
	Roads and bridges	Y	-84%	-0.28	-0.28
	Airports	Y	64%	0.21	0.21
	Railways		47%	0.00	0.00

A questionnaire (Annexe 3) was used to determine the average infrastructure orientation for each of the sub-factors (n = 37). Each factor was scaled between 1 – 5, where: 1 = “Extremely not important”; 3 = “Neutral”; and 5 = “Extremely important”. Infrastructure orientation for each sub-factor was then given a sign (positive or negative) to reflect whether stakeholders thought that the land use associated with a specific sub-factor was compatible with infrastructure or in conflict (eq. 2). For example, all the stakeholders thought that infrastructure development was incompatible with conservation areas.

As described in Chapter 3, we then identified the best available spatial data that could be used to represent each of these factors (Figure 5.3). In some cases data was not available to represent each of the sub-factors so we then calculated the cost for each spatial layer as a property of the total number of spatial layers available per factor (eq. 2). For example, the factor “B. Water habitat and resources” was had two spatial layers and thus infrastructure orientation values were divided by 2. This approach was used so that factors that had multiple sub-factors with available spatial layers were equally weighted in the cost surface as factors with very few sub-factors e.g. “B. Water habitat and resources” has 3 sub-factors versus “D. Industrial activities” which has 5. An alternative approach if all spatial data was available for each sub-factor would be to weight each layer as a proportion of the number of sub-factors within a factor group (eq. 3).

$$Infrastructure\ orientation = \frac{Average\ response - 1}{4} \text{ (eq. 1)}$$

$$Orientation\ weighted\ by\ available\ data = \frac{infrastructure\ orientation}{total\ number\ of\ subfactors\ with\ available\ spatial\ data} \quad \text{(eq. 2)}$$

$$Orientation\ weighted\ by\ num.subfactors = \frac{infrastructure\ orientation}{total\ number\ of\ subfactors} \quad \text{(eq. 3)}$$

Along with the sub-factor spatial data a topographical dataset was used to derive a map of terrain slope across the region (Figure 5.4). Slope was classified into the following categories based on suitability classes identified by the Indonesian transportation department categories and the costs were derived from a survey of the literature and discussions with experts:

< 3^0 Suitable	no cost
3^0 – 25^0 No suitable	double cost
>25^0 Very unsuitable	five times the cost

The cell values of each of the weighted spatial sub-factor layers were then added to the topographical cost surface to produce a total cost-surface. The processing below was conducted using a 100 m cell size. This cell size represents and optimum pixel size for the spatial data input layers and also the appropriate physical size of the infrastructure tested.

Figure 5.3 Maps of sub-factors used to create-cost surface

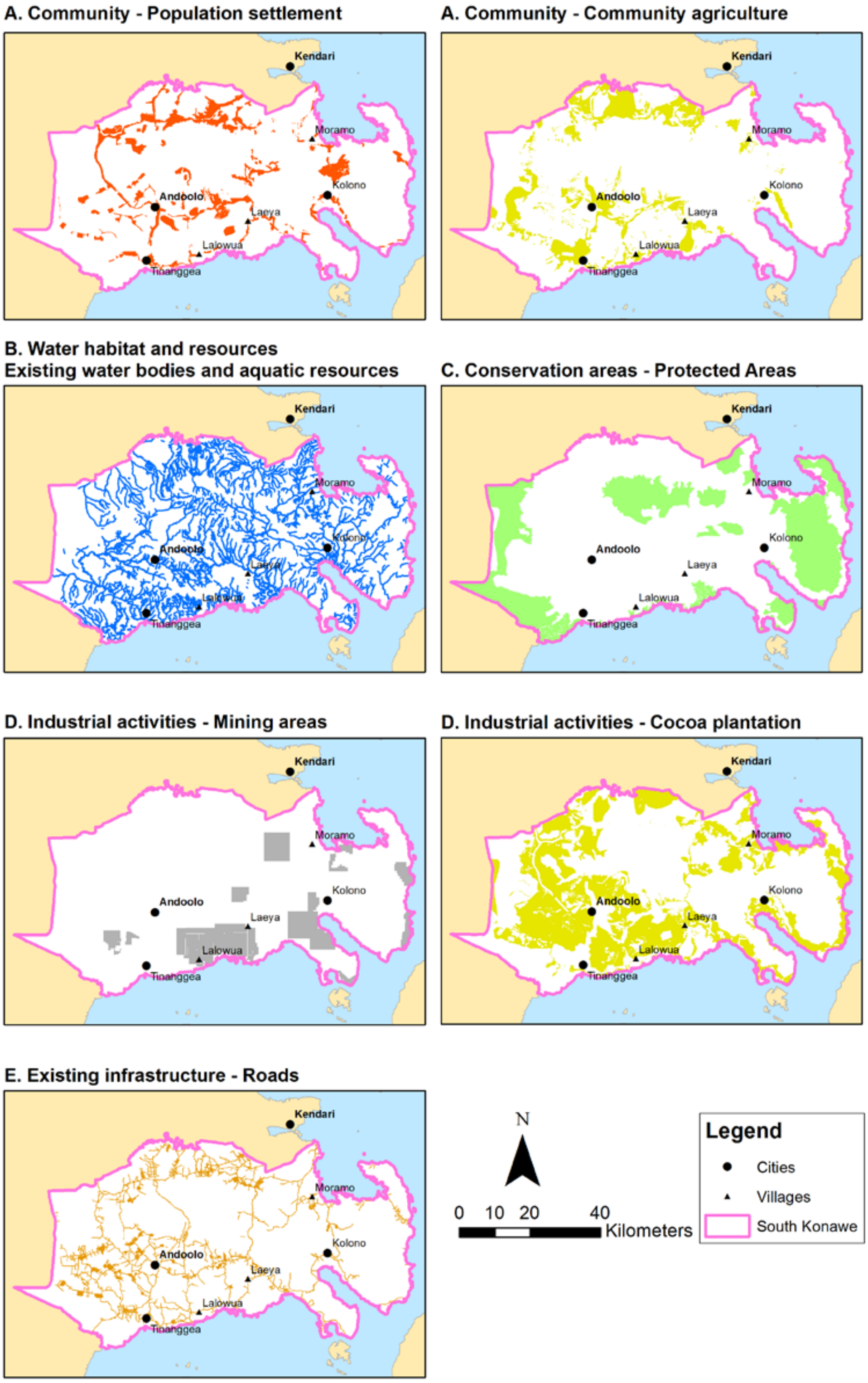


Figure 5.4 Classified slope spatial data derived from topographical data categorised into categorises based on suitability for roads.

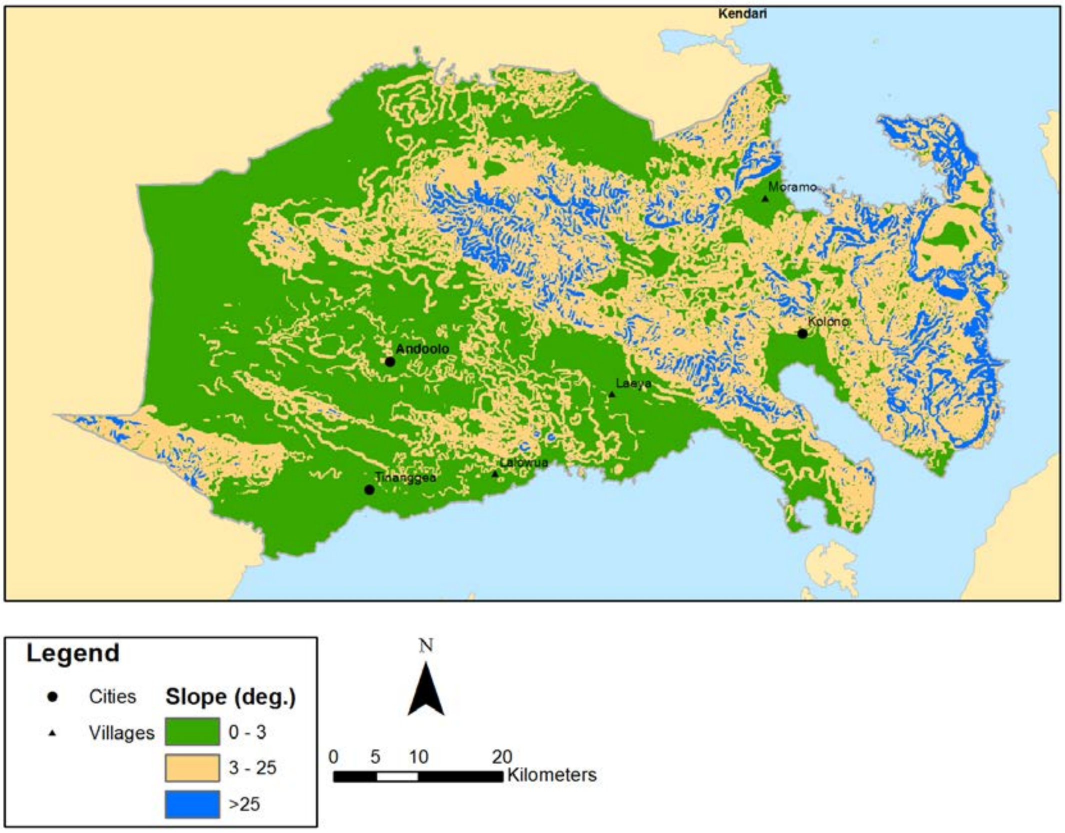
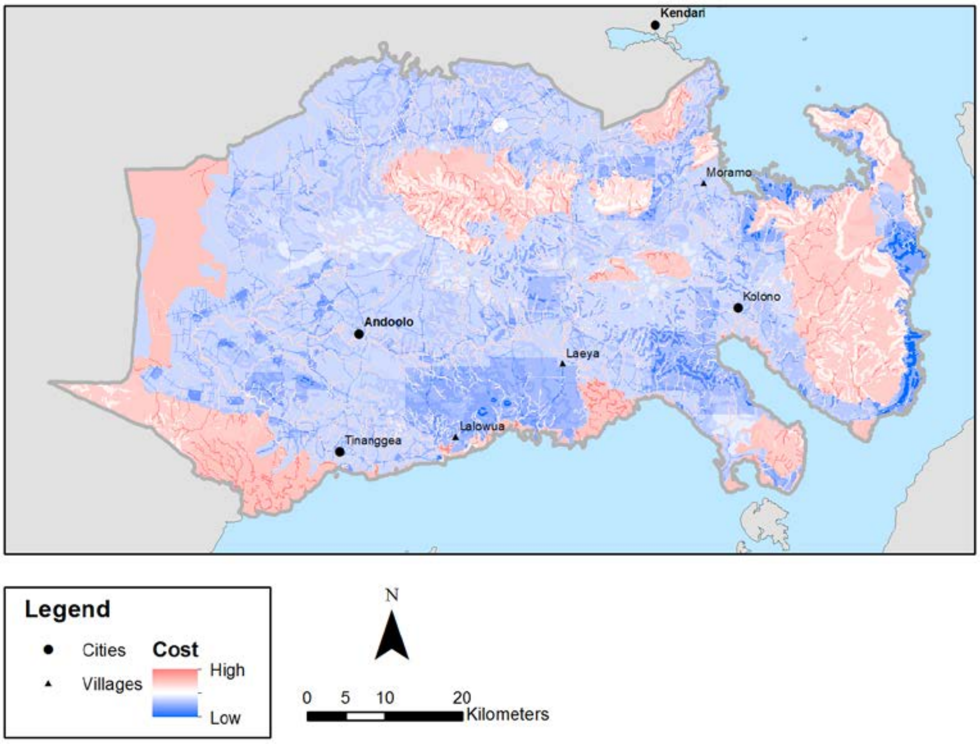


Figure 5.5 Cost-surface produced through combining all weighted GIS layers representing each of the sub-factors where spatial data was available.



We used the graph-based least-cost path analysis software Graphab (Foltête et al. 2012) for deriving the least-cost paths. This software was originally developed for modelling ecological connectivity. The process of producing the cost-surface was automated in a freely available software tool using the Python programming language utilising the ArcGIS 10.1 Python libraries (see Annexe 5). The Python script provides an example of how the spatial data processing may be automated to allow fast an accurate geoprocessing of spatial input data layers, however, every project is likely to require the modifications of the original Python script.[13]

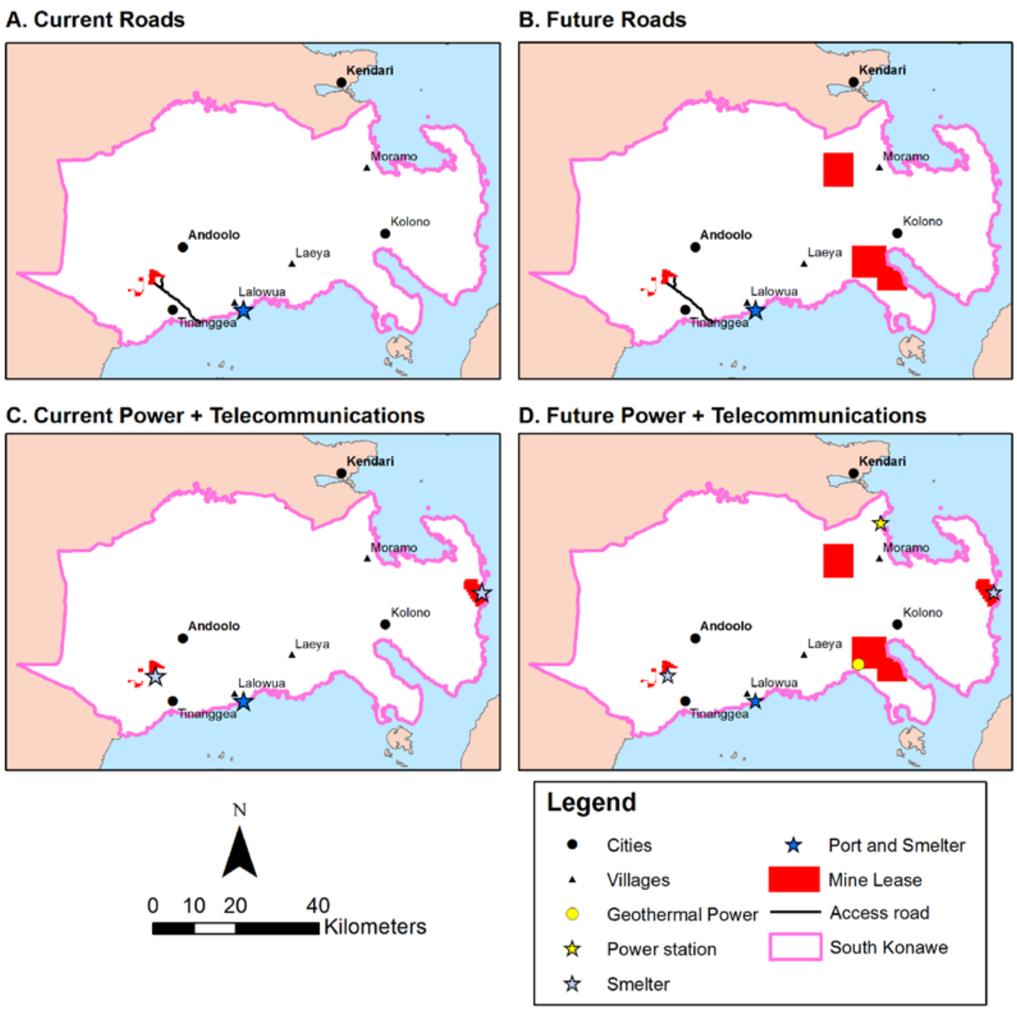
5.3.2 Scenarios

Through discussion with stakeholders we identified three forms of linear mine infrastructure: electricity, fixed-line telecommunications, and roads. These infrastructures may need to link up mines to supporting infrastructure such as ports, smelters and power stations. We treated electricity and fixed-line telecommunications

[13] The tool is opensource and license free and may be downloaded from: https://github.com/AlexLechner/Infrastructure-network-processing-tool

as one as they are likely to share the same infrastructure and are likely to need the same considerations. Thus, we modelled two types of linear infrastructure: i) roads and ii) power lines and telecommunications (Figure 5.6). We then identified existing and future infrastructure needs for each type of infrastructure. Existing infrastructure needs represent current or soon to be operating mines and supporting infrastructure (ports and smelters) that need to be linked; while future infrastructure represents future (projecting) developments that are being planned. In total we tested 4 scenarios (2 linear infrastructure types × 2 time periods). For the road scenarios we included an existing access road which was given a low cost value (Figure 5.6A and B). These scenarios represented possible planning scenarios and do not reflect stakeholder consensus. They are purely to provide an example of how the spatial method may be used.

Figure 5.6 Four scenarios based on current and future infrastructure demands. In each scenario the mine leases, ports, smelters and power stations need to be linked.



5.4 Results

The least-cost path analysis identified pathways which connected all nodes in the landscape. The network analysis also identified the minimum spanning tree which describes a network of least-cost paths with the minimum number of links connecting all nodes in a landscape. Figure 5.7 describes the output from the current and future scenario for power and telecommunications. In both scenarios the least-cost paths avoided high cost areas in the pink colour that predominantly included areas of conservation value. The pathway in Figure 5.7 and Figure 5.8 linking the smelter on the coast to the east avoids the large area of forest that also includes areas with high slope and thus high cost.

Figure 5.7 Current and future power and telecommunications scenarios.

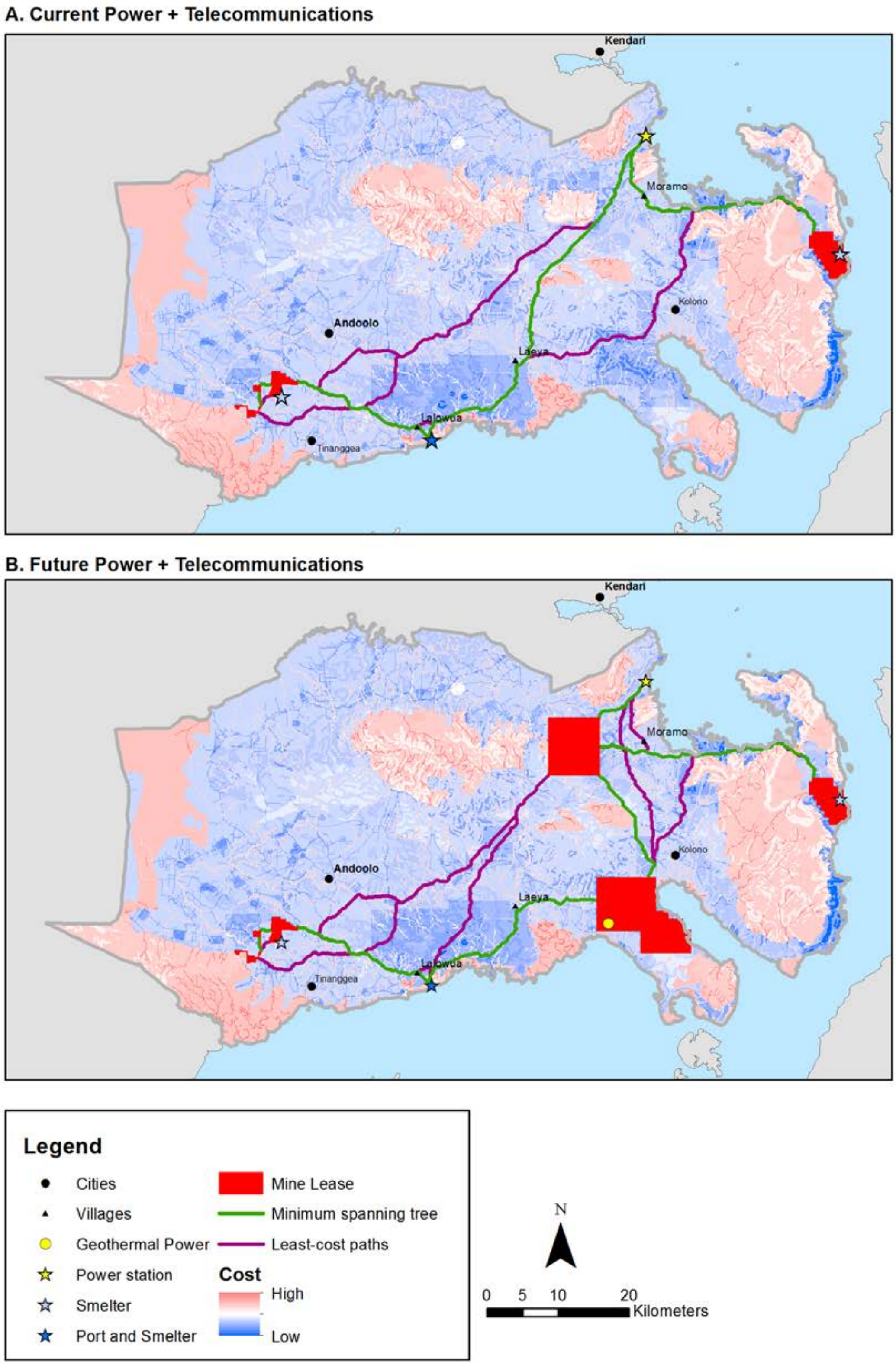
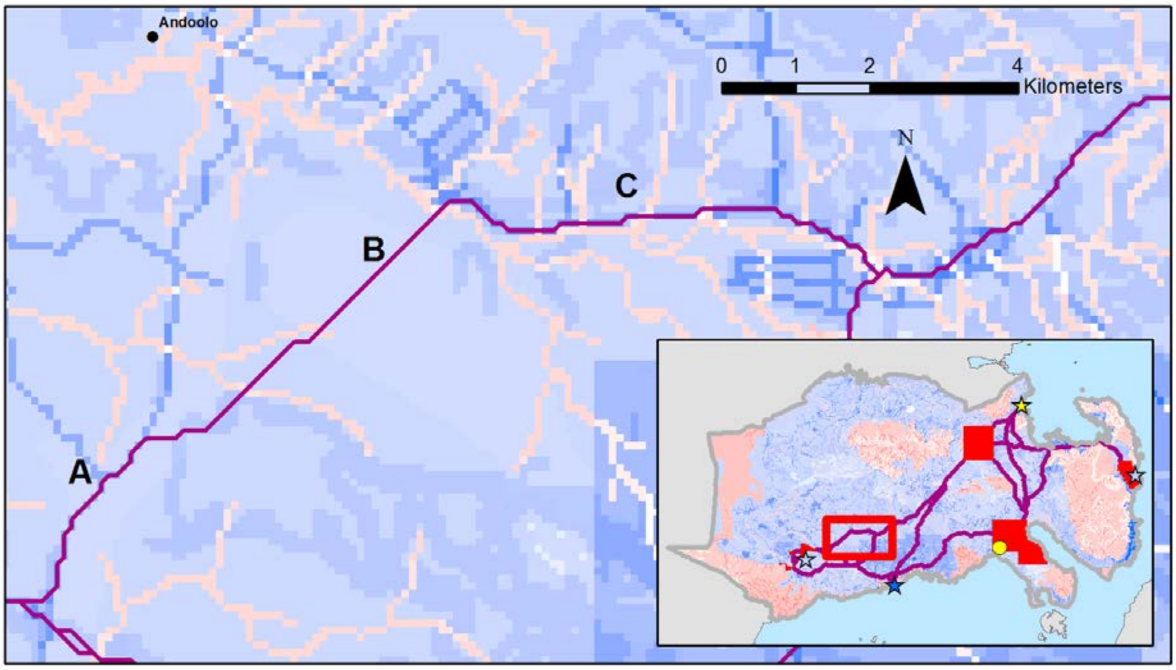


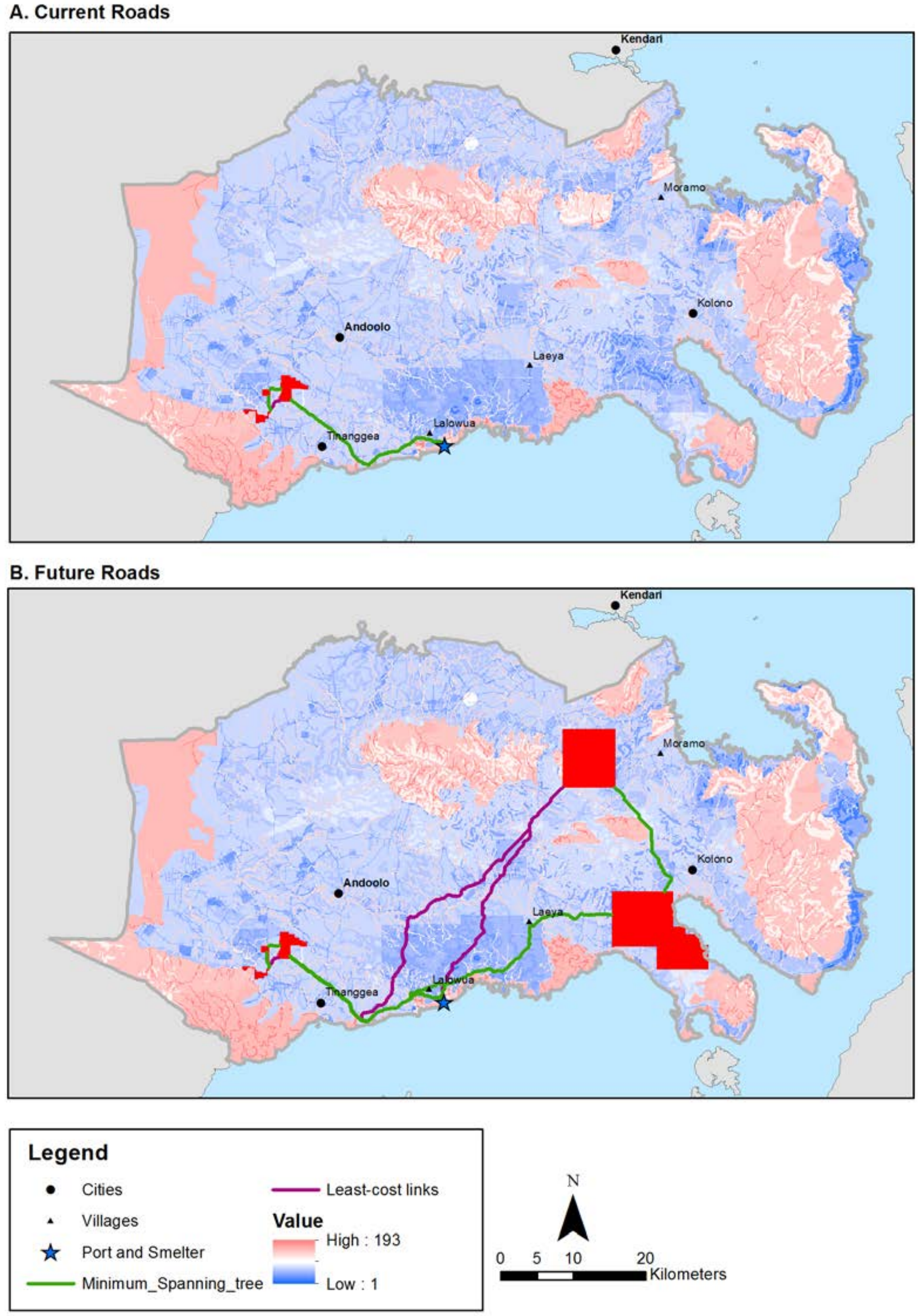
Figure 5.8 Example of least-cost path algorithm



Example of least-cost path algorithm for the future power and telecommunications scenario. A) location where the least-cost pathway follows low-cost (high infrastructure orientation) pixels (dark blue) that represent population settlements, low slope and don't include low infrastructure orientation factors such as protected areas. B) Union form region where all pixels have same value and thus the least-cost path is a straight line. C) Location in which the least-cost path avoids areas of low infrastructure orientation associated with the river.

Figure 5.9 describes a least-cost path network for current and future road scenarios. Note that that the least-cost path in the west near Tinanggea follows an existing access track that connects a nickel mine to a private port near the coast. In the current road scenario there are few locations to be connected as in the study area the majority of transportation of minerals takes place via boats.

Figure 5.9 **Four scenarios based on current and future infrastructure demands. In each scenario the mine leases, ports, smelters and power stations need to be linked.**



5.5 Discussion

The method described in this chapter represents a systematic quantitative approach for evaluating the optimal locations for building linear infrastructure. Our least-cost path modelling method emphasises the linkages between natural and human systems across disciplines using a spatially explicit integrated systems based approach. Spatial analyses are important for regional planning as the spatial configuration of landcover elements can be just as important as the preferences identified in the social analysis. For example, conservation areas and which have a large relative area have little effect on the least-cost paths as they are found in the middle of the study region.

The results of the current analysis represent only the first step in what should be an iterative process lead by a regional planning organisation in consultation with stakeholders (see Chapter 4). This case study provides an example of how such tools could be used for developing infrastructure. An actual regional planning process would be a multi-million dollar exercise involving numerous government departments, consultants and stakeholders, and thus beyond the scope of our research project. However, we believe the quantitative approach described here provides a framework for more transparent, evidenced-based planning. The following list provides a summary of the potential ways in which modelling outputs could be improved based on our case-study with local community members and government:

- Identify and map spatial data for sub-factors without existing data
- Improve the positional accuracy of the spatial data within areas that the least-cost paths have been mapped through discussion with local community.
- Improve the thematic accuracy of the spatial data in terms of how well they reflect the sub-factor that they are meant to represent.
- Incorporate actual costs per kilometre of infrastructure identified through an engineering study.

All of the above issues associated with how well the spatial data reflect the sub-factors may need to be addressed as spatial uncertainty can occur as a result of the process of combining, rescaling and spatially explicit modelling (see Gotway & Young, Box 5-1 2002; Comber et al., 2005; Lechner et al., 2012). Further analysis testing the sensitivity of the least-cost outputs to the uncertainty in the input data is recommended, but beyond the scope of this study.

Our approach should not be used prescriptively. It should be included as just one of the decision support tools for land use planning. Using a participatory approach, through multiple iterations of the model the accuracy of the least-cost outputs and how well they reflect stakeholder preferences can be improved.

CHAPTER 6: CONCLUSION & RECOMMENDATIONS

6.1 Summary

This final chapter provides a number of conclusions and recommendations to assist planners to incorporate socio-ecological factors, and the perspectives of potentially impacted communities, into the mineral infrastructure planning process. The first section provides a number of conclusions and key lessons that emerge from the discussion in the previous chapters. The final section brings together the methods and tools described in the report by outlining a nine step process for using participatory GIS in mineral infrastructure planning.

6.2 Conclusions And Key Lessons From The Research

6.2.1 Early And Well-Coordinated Mineral Infrastructure Planning Can Minimise Environmental And Social Costs

Government underinvestment in basic infrastructure remains a critical constraint in promoting sustainable extractive industry investments. Current efforts to develop mineral infrastructure are largely dependent on mining companies and their infrastructure needs. It is apparent that at present, many regional spatial documents fail to accommodate early planning of mineral infrastructure needs. Consequently, the majority of mineral infrastructure is built according to the short-term needs of mining companies which has limited the flow-on benefits to surrounding communities.

To promote sustainable mineral infrastructure, we suggest that well-coordinated and early planning is promoted to prevent and mitigate environmental and social costs of mining activities and their associated impacts including the transportation of minerals from pit to port.

6.2.2 Government And Mining Companies Need To Work Collaboratively To Ensure Appropriate Standards Of Mineral Infrastructure Including Its Maintenance

From our field observations in the case study regions, the quality of mineral infrastructure is varied between large scale and small/medium mining operations. Large scale mining operations appear to have higher standards and requirements for mineral infrastructure to support longer term mine operations (which are often decadal timeframes). However, small- to medium-scale mining operations tend to build their mineral infrastructure with basic and cheaper options to cater for mining operations that may often occur across a significantly less timeframes (often less than five years) than their larger counterparts As a result, from our field observations it was apparent that infrastructure was constructed without considering the environmental and social costs. This was evidenced in the South Konawe case study regions (i.e. the destructions of mangrove, poor standards of ports and roads, three overlapping mining ports within the same coastal areas). Furthermore, it was apparent that many mineral infrastructure projects in South Konawe had been abandoned once the small-scale mining operations ceased (e.g. due to the introduction of raw material ban; or due to bankruptcy as the operation was no longer economically viable).

To avoid further impacts of ad-hoc and sporadic mineral infrastructure development, we suggest that the national and sub-national government revisit and revise its infrastructure policy for extractive industries (e.g. exclusively built mineral infrastructure for specific mining operations). A further study needs to be conducted to investigate the opportunities of co-location or co-sharing infrastructure corridors. This is pertinent for the medium- and small-scale mining operations as well as for the large scale mines to ensure the prosperity of the region.

6.2.3 Improving Land Use Policies And The Use Of Gis For Pro-Active Planning Purposes

We found that there are some significant barriers in promoting better land-use management in Indonesia and especially so for the case study regions. Through our interviews with key respondents (namely planners and development practitioners) there is a clear lacking of coordinated, long term, strategic land use assessment and decision making. This is a key barrier to the promotion and uptake of sustainable development in Indonesia. To aid more systematic land use decision making, a lead government agency should be given responsibility in bringing relevant land use information together in a consistent fashion and for making that information publicly available. We suggest that productive lands for community livelihoods and other economic activities need to be protected against inappropriate mineral infrastructure encroachments. Similarly, key water bodies and conservation areas (including protected areas) need to be avoided in the mineral infrastructure planning.

GIS can facilitate better land-use management and negotiation. However, we found that GIS has not been used optimally by the national and local planners. Key respondents suggested that GIS is currently being used only to display existing infrastructure. We recommend that GIS can be utilised as a progressive planning tool to accommodate the rapidly changing land-use situation occurring within Indonesia. Through our research, we have developed a methodology for GIS to incorporate relevant and measurable socio-ecological factors for better mineral infrastructure planning in Indonesia.

6.2.4 Accurate Geo-Spatial Data Supports Better Gis Modelling

In conducting our research, there were challenges in collecting and assessing geo-spatial data due to three factors. First, there are multiple geo-spatial data sources with non-unified data formats and no meta-data to trace back the history of a particular map/layer. Each agency tends to release and utilise their own data which can often be inconsistent when compared with data released by another agency. Secondly, the coverage of geo-spatial data is incomplete and this created difficulties in undertaking a comprehensive analysis with real-time data. Thirdly, spatial data governance and management are poor at the sub-national government level and this is apparent in relation to the procedures of data collection, maintenance and data sharing.

We suggest that geo-spatial data at the national and sub-national level can be improved to support and facilitate better mineral infrastructure planning in Indonesia. With the limitations above, we have provided insights on: GIS layers (Chapter 3); how those layers can be utilised in the land-use suitability and proximity analysis (Annexe 4); and progressive linear infrastructure planning (Chapter 5).

6.2.5 A GIS Based Mineral Infrastructure Tool Is Conducive To Enabling Active Community Participation In Decision-Making

In Chapter 4, we suggested some methods for community engagement as part of our mineral infrastructure tools/methodology. The essence of community engagement is to create conducive environment and active community participation in mineral infrastructure planning. The regional planners should have the skills for better participatory GIS planning in mineral infrastructure planning.

6.2.6 The Findings Of This Study Can Provide A Platform For Future Studies And Future Leverages

Finally, we suggest the research findings and deliverables can serve as a productive platform to trigger further research in the mineral infrastructure, participatory GIS and integrated infrastructure planning. This is especially important when considering the role of social and ecological interactions and systems. As results of this study, we suggest several further research themes that can be conducted, namely:

- Deliberating and applying participatory GIS planning at the community level
- Mainstreaming mineral infrastructure planning and its policy implication
- Applying the tool to specific major infrastructure projects including the consideration of its engineering aspects
- Further developing a practical guideline for specific mineral infrastructure (e.g. railway, road, and others)
- Understanding the nature of public–private partnerships in promoting equitable mineral infrastructure development

For future leverage from this research we value the partnership that has been developed between ITB and UQ and consider that the research partnership can be further strengthened as a result of this research. Furthermore, it would be beneficial to transfer the knowledge created through this research to our local partners from private and government institutions in both case study regions, as described below.

6.2.7 Knowledge Transfer And Capacity Building

The methods and GIS tool for mineral infrastructure planning outlined in this research should be disseminated to key partners in the two case study provinces in the first instance and, ideally, to other provincial government departments involved in mineral infrastructure planning. This represents an opportunity to improve infrastructure planning so as to incorporate socio-ecological factors, but would also draw on the vast wealth of knowledge of local infrastructure planning issues across Indonesia's provinces to improve the tools. Ultimately, such a strategy would lead to greater buy-in of the approach outlined. In conjunction with our partners at ITB the research team will aim to explore opportunities for knowledge transfer and capacity building during early 2016.

6.3 A 9 Step Process For Using Participatory Gis In Mineral Infrastructure Planning

This final section of this chapter provides high level step by step guidance for land use planners and GIS officers on how to construct and use a participatory GIS when planning mineral infrastructure corridors and networks at the sub-national (city and regency) level. The guide, which is offered in the form of a 9-step process, is intended to be a draft working document that outlines one approach. Subject to feedback, the Guide may require further elaboration before it can be used in the field. Reference is made throughout this guide to the main report (*Socio-ecological Tools in the Development of Mineral Infrastructure*), and users are encouraged to refer to relevant chapters and sections for further information.

The guidance is primarily intended to be used in the context of new greenfield mineral regions which can benefit from the designation of corridors that have been designed with a sensitivity to the local social and ecological environment (i.e. 'socio-ecological Factors').

Step 1: Understand Existing Spatial Planning And Sustainability Frameworks In Your Administrative Area(s) (See Chapter 2)

A first step is to ensure you understand existing spatial planning and sustainability / environmental regulatory frameworks in your administrative area. Information on the broader spatial and infrastructure planning frameworks in Indonesia can be found in chapter 2. Some of the questions you should be considering to understand the relevant regulatory frameworks in order to conduct a GIS analysis include:

- What is required by regulation in your administrative area(s) (e.g. by AMDAL processes) and how would these regulations influence the design of the corridor?
- Is there an existing sustainability vision/policy that should inform the design of a GIS tool?
- What is in the regional development plan?
- Has a Strategic Environmental Assessment (SEA) been undertaken?
- Are there any urban development and /or growth plans that should be considered?

- Are there any key principles, such as economic connectivity, that will significantly influence the design of the infrastructure corridor?[14]

Step 2: Identify Current, Planned And Potential Mineral Infrastructure

Engage with key stakeholders (government planners, industry bodies, resource companies) to understand current and future infrastructure needs. This will include identifying the following:

1. Key geographic locations (focal points/nodes) that may need to be connected through mineral infrastructure e.g. current and future mines, power stations, smelters and ports
2. Existing and future roads, rail and power networks that may be connected with, or contribute to. mineral infrastructure

The aim here is not to come up with a definitive list of every single road or port that might be needed for each deposit, but rather to obtain a general understanding of:

- The types of infrastructure that would likely be required to develop different minerals in the region
- The mineral deposits most likely to be developed over the next decade
- Likely paths/routes or locations needed to accommodate this infrastructure (without taking into account any socio-ecological factors / constraints)
- The known location of endpoints (e.g. ports).

The consultations with key stakeholders can occur within the context of one-on-one interviews and / or workshops with representatives of government, industry, experts and other stakeholders (see Chapter 4). It is recommended that those conducting the stakeholder engagement bring hard copies of base maps of the region to meetings and workshops, which can be populated to record information, for example on the location of planned infrastructure networks that may not be currently be mapped.

Step 3: Scope/Identify Any Existing Gis Capacity Including Planning Tools And Data

Identify existing and potential capacity for carrying out GIS analysis for infrastructure corridor planning by considering the following questions:

- Does your department / agency currently use, or have access, to a GIS?
- Which system to use (e.g. open-access versus commercial product)?

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[14] See Leslie (2013) for a discussion of the concept of connectivity as a key principle in spatial prioritisation in the context of mapping

- What kinds of data are available and what are they used for?
- Who owns the spatial data – licensing etc.?

STEP 4: SELECT AND EVALUATE FACTORS TO BE INCLUDED IN THE GIS (SECTION 3.2.1 AND CHAPTER 4)

Identify and assess important social and environmental factors that should be considered during the mineral infrastructure planning process. This is undertaken through a desktop review and stakeholder engagement activities (Chapter 4). Specifically, it involves:

1. Identifying potential socio-ecological factors through a desktop study of existing literature, preferably focusing on factors that may be relevant to your administrative area / region.
2. Validating and refining the proposed socio-ecological factors through stakeholder engagement with all key groups and quantitative weighting surveys (including Likert scales). This will result in the creation of a **preliminary list of factors** ranked in order of their importance to the planning process, as assessed by stakeholders.

It is critical that the stakeholder engagement process is well thought out and these stakeholders are representative of key groups in the administrative area / region (see chapter 4).

STEP 5: COLLECT, MANAGE AND PROCESS AVAILABLE GIS DATA FOR THE PRELIMINARY FACTORS IN ORDER TO GENERATE MAPS

Step 5a: Collect

The first part of step 5 involves undertaking some research to see what GIS data is available for the **preliminary list of factors** identified in Step 4. Important considerations here include determining whether the socio-ecological factors in the preliminary list are actually map-able and that there is available good quality and reliable data on each factor. At this point it is important to take note of the following issues:

i) There will be socio-ecological factors that can be mapped and for which there is data available;

ii) Some factors can be mapped but no data will be available; and

iii) Some factors are difficult or impossible to map.

Examples of the type of data that may be available include:

- Minerals data (e.g. ore deposits in a region, leases, exploration permit data, existing mineral infrastructure data)

- Data on 'standard' factors such as land use, water bodies, urban centres, existing infrastructure, locations of current and proposed economic activity
- Data on 'non-standard' socio-ecological factors (e.g. conservation forests, wetlands etc.)

Examples of the factors that are often not mapped but can be mapped include:

- Community forests, common grazing lands, areas of cultural and spiritual significance, traditional hunting grounds etc.

Examples of factors that are difficult or impossible to map include:

- The aesthetic value of a community forest to individuals/communities.

Step 5b: Manage, Process And Address Potential Data Quality Issues (Accuracy, Scale, Currency Etc.)

This second part of Step 5 is a generic GIS task whereby data quality such as the accuracy and currency of the data is inspected to ensure that it is fit for purpose. This includes:

- Basic data management methods – identifying subsets from aggregate datasets that reflect the preliminary list of factors, for example extracting plantation land cover classes from a land use and land cover dataset.
- Addressing common problems with data: quality (e.g. incompleteness, wrong scale, accuracy) – perhaps minor editing/updating

The list of factors for which there are GIS data of the appropriate quality is known as the **intermediate list of factors.**

Step 5c: Generate Maps Of Intermediate List Of Factors And Focal Points/Nodes (E.G. Mine Operations)

The final part of Step 5 involves creating GIS maps that show the distribution of the intermediate list of factors (from step 5b) and focal points/nodes (Step 2).

Step 6: Engage Stakeholders To Ground Truth, Refine, And Generate New Data

Using the guidelines provided in chapter 4, develop an engagement plan that will allow you (or a nominated partner) to seek the input of key stakeholders in order to do the following:

- Ground truth **the intermediate list of factors**. This involves addressing the following questions:

- Does the data have adequate spatial data quality from the perspective of the local stakeholders (e.g. do official land tenure boundaries reflect local understandings?).
- Do the GIS layers reflect the stakeholders' conceptual understanding of the social-ecological factors? For example, the research may have identified high value conservation forest, as identified by scientists. However, conservation scientists may measure biodiversity value in terms of abundance of flora and fauna, while stakeholders may consider biodiversity to be reflected by the presence of charismatic fauna (e.g. tigers, orang utan, etc).

- Refine
  - Address issues identified in the ground truthing exercise by updating, replacing or altering existing layers.
- Generate new data
  - For those factors where spatial data is not available it may be necessary to conduct community mapping, if practical. Techniques for community mapping to generate new GIS data are described in chapter 6.

It may be necessary to build people's capacity to make informed decisions about which factors might be included in the GIS. This might entail developing some basic information sheets about what you are doing, what the benefits of infrastructure corridor planning are, and what kinds of factors are being considered and why (e.g. what an infrastructure corridor is, why infrastructure planning should take into consideration factors such as conservation forest or wetlands).

Create **final list of factors** along with associated GIS data.

Step 7: Conduct Least-Cost Path Analysis (Chapter 5)

This step involves using the least-cost path analysis described in chapter 5 to:

- conduct GIS mapping in order to identify linear infrastructure networks for multiple scenarios; and
- Generate scenario maps showing linear infrastructure networks.

Step 8: Deliberations Over Mineral Infrastructure Corridor Scenarios During Planning Workshops

The final step in this process is present infrastructure scenarios to a multi-stakeholder group in planning workshops. The purpose of this process is to:

- Identify planning infrastructure corridor/network scenarios that can be assessed based on whether they reflect stakeholders' social and environmental preferences. For example, does the corridor/network go around a location of spiritual significance to indigenous peoples etc.?

- Evaluate how the scenarios enable the realisation of potential economic opportunities presented by the development of new infrastructure. For example, does the corridor avoid connecting a town centre which could benefit from new power?
- Assess whether the infrastructure corridor is technically feasible given engineering and financial constraints. For example, does the corridor meander to such a degree that it is too costly?

The outputs can be refined and the least-cost analysis can be rerun in response to the workshop feedback.

Step 9: Adaptive Planning

The process described above is likely to be ongoing and the infrastructure planning maps can be refined in response to new data, new developments, changes to stakeholder preferences, and changes regulation and planning frameworks.

ANNEXES

Annexe 1: Background Materials / References

Antara News, 2012, 'Dispute Mediation Council of South East Sulawesi Ifishdeco with Residents', Antara News, viewed 10 October 2014, <http://antarasultra.com/berita/263370/dprd-sultra-mediasi-sengketa-ifishdeco-dengan-warga>

Bagli, S, Geneletti, D & Orsi, F 2011, 'Routeing of power lines through least-cost path analysis and multicriteria evaluation to minimise environmental impacts', *Environmental Impact Assessment Review*, vol. 31, no. 3, pp. 234-239, doi: 10.1016/j.eiar.2010.10.003.

Brown, G 2012, 'Public Participation GIS (PPGIS) for regional and environmental planning: reflections on a decade of empirical research', *Journal of Urban and Regional Information Systems Association*, vol. 25, no. 2, pp. 7-18.

Business Monitor International, 2013, *Indonesia Mining Report*, Quarter 3 2013.

Collins, M, Steiner, F & Rushman, M 2001, 'Land-use suitability analysis in the united states: historical development and promising technological achievements', *Environmental Management*, vol. 28, no. 5, pp. 611-621.

Comber, A, Fisher, P & Wadsworth, R 2005, 'You know what land cover is but does anyone else? an investigation into semantic and ontological confusion', *International Journal of Remote Sensing*, vol. 26, no. 1, pp. 223-228.

Devi, B & Prayogo, D 2013, *Mining and Development in Indonesia: An Overview of the Regulatory Framework and Policies*, IM4DC Action Research Report.

Dodgson, J, Spackman, M, Pearman, A & Phillips, L 2015, *Multi-criteria analysis: a manual*, Department for Communities and Local Government, London.

Foltête, J, Clauzel, C & Vuidel, G 2012, 'A software tool dedicated to the modelling of landscape networks', *Environmental Modelling & Software*, vol. 38, pp. 316-327.

Gahlot, V, Swami, B, Parida, M & Kalla, P 2012, 'User oriented planning of bus rapid transit corridor in GIS environment', *International Journal of Sustainable Built Environment*, vol. 1, no. 1, pp. 102-109, doi: 10.1016/j.ijsbe.2012.07.004.

Gerber, L 2013, *Accelerating Indonesia's Infrastructure Development*, Working Paper, US State Department, Spring 2013.

Goldberg, C, Pocewicz, A, Nielsen-Pincus, M, Waits, L, Morgan, P, Force, J & Vierling, L 2011, 'Predictions of ecological and social impacts of alternative residential development policies to inform decision making in a rural landscape', *Conservation Letters*, vol. 4, no. 6, pp. 423-432, doi: 10.1111/j.1755-263X.2011.00194.x.

Goodchild, M, Anselin, L, Appelbaum, R & Harthorn, B 2000, 'Toward spatially integrated social science', *International Regional Science Review*, vol. 23, no. 2, pp. 139-159, doi: 10.1177/016001760002300201.

Gotway, C & Young, L 2002, 'Combining Incompatible Spatial Data', *Journal of the American Statistical Association*, vol. 97, no. 458, pp. 632-648, doi: 10.1198/016214502760047140.

Grassi, S, Friedli, R, Grangier, M & Raubal, M 2014, 'A GIS-Based Process for Calculating Visibility Impact from Buildings During Transmission Line Routing', in J Huerta, S Schade & C Granell (ed), *Connecting a Digital Europe Through Location and Place, 383 Lecture Notes in Geoinformation and Cartography*, Springer International Publishing Switzerland, pp. 383-402.

IFAD, 2009, Good practices in participatory mapping: A review prepared for the international fund for agricultural development, viewed 6 April 2015, <http://www.ifad.org/pub/map/pm_web.pdf>.

International Council on Mining and Metals (ICMM), 2009, *Good Practice Guide: Indigenous People and Mining*, ICMM, London, <https://www.icmm.com/document/1221>.

Lechner, A, Brown, G & Raymond, C 2015, 'Modeling the impact of future development and public conservation orientation on landscape connectivity for conservation planning', *Landscape Ecol*, vol. 30, no. 4, pp. 699-713, doi: 10.1007/s10980-015-0153-0.

Lechner, A, Langford, W, Bekessy, S & Jones, S 2012, 'Are landscape ecologists addressing uncertainty in their remote sensing data?', *Landscape Ecol*, vol. 27, no. 9, pp. 1249-1261, doi: 10.1007/s10980-012-9791-7.

Lechner, A, Raymond, C, Adams, V, Polyakov, M, Gordon, A, Rhodes, J, Mills, M, Stein, A, Ives, C & Lefroy, E 2014, 'Characterizing spatial uncertainty when integrating social data in conservation planning', *Conservation Biology*, vol. 28, no. 6, pp. 1497-1511, doi: 10.1111/cobi.12409.

Lesslie, R 2012, 'Mapping our priorities – innovation in spatial decision support', in P Figgis, J Fitzsimon & J Irving (ed), *Innovation for 21st Century Conservation*, Australian Committee for IUCN Inc., pp. 156–163.

Longley, P, Goodchild, M, Maguire, D & Rhind, D 2011, *Geographic Information and Science*, 3rd edn, Wiley and Sons, Hoboken.

Malczewski, J 2004, 'GIS-based land-use suitability analysis: a critical overview', *Progress in Planning*, vol. 62, no. 1, pp. 3-65.

Malczewski, J 2006, 'GIS-based multicriteria decision analysis: a survey of the literature', *International Journal of Geographical Information Science*, vol. 20, no. 7, pp. 703-726, doi: 10.1080/13658810600661508.

Nyeko, M 2012, 'GIS and multi-criteria decision analysis for land use resource planning', *JGIS*, vol. 04, no. 04, pp. 341-348,

OECD, 2010, *OECD Economic Surveys: Indonesia,* viewed 15 October 2014, <http://www.oecd.org/eco/surveys/2012%20Indonesia%20Overview.pdf>

Peluso, N. L. (1995) Whose woods are these? Counter-mapping forest territories in Kalimantan, Indonesia. Antipode, 27: 383-406

Polyakov, M, Panell, D, Pandit, R, Tapsuwan, S & Park, G 2013, 'Valuing environmental assets on rural lifestyle properties', *Agricultural and Resource Economics Review*, vol. 42, no. April 1, pp. 159-175.

PWC, 2012, *Mining in Indonesia: Investment and Taxation Guide*, 4th Edition, April 2012.

Ramirez-Gomez, S, Brown, G & Tjon Sie Fat, A 2013, 'Participatory mapping with indigenous communities for conservation: challenges and lessons from Suriname', *The Electronic Journal of Information Systems in Developing Countries*, vol. 58, no. 2, pp. 1-22.

Sitzia, T, Rizzi, A, Cattaneo, D & Semenzato, P 2014, 'Designing recreational trails in a forest dune habitat using least-cost path analysis at the resolution of visitor sight distance', *Urban Forestry & Urban Greening*, vol. 13, no. 4, pp. 861-868, doi: 10.1016/j.ufug.2014.09.011.

State of Queensland, 2005, *Engaging stakeholders: Community engagement in the business of government*, State of Queensland, Brisbane, <https://www.qld.gov.au/web/community-engagement/guides-factsheets/documents/engaging-queenslanders-business-gov.pdf>.

Stanley, M & Mikhaylova, E 2011, *Mineral Resource Tenders and Mining Infrastructure Projects Guiding Principles*, World Bank, viewed 9 October 2014, <http://siteresources.worldbank.org/INTOGMC/Resources/EITI22weboct17.pdf>.

Sustainable Development Solutions Network, 2013, *Harnessing Natural Resources for Sustainable Development: Challenges and Solutions*.

Surjono, Qurbani, I, Rahayu, R n.d., *A Contra Productive Policy in Natural Resource Rich Region: the case of coal mining in East Kalimantan, Indonesia*, Department of urban and Regional Planning, Faculty of Engineering, University of Brawijaya, viewed 14 April 2014, <http://surjonopwkub.lecture.ub.ac.id/files/2014/03/A-contra-productive-policy-in-natural-resource-rich-region-for-pensee.pdf>

Sutanta, H 2012, 'Spatial Planning Support System for an Integrated Approach to Disaster Risk Reduction', PhD Thesis, University of Melbourne.

Toledano, P, Thomashausen, S, Maennling, N, Shah, A 2014, 'A framework to approach shared use of mining-related infrastructure', Vale Columbia Center on Sustainable International Investment, Columbia University, New York.

Vajjhala, Shalini, 2006, "Ground Truthing" Policy Using Participatory Map-Making to Connect Citizens and Decision Makers. Resources for the Future, viewed 14 November 2015, <http://www.rff.org/files/sharepoint/WorkImages/Download/RFF-Resources-162_GroundTruthing.pdf>

Wang, S, Liu, C & Zhang, H 2011, 'Suitability evaluation for land reclamation in mining area: A case study of Gaoqiao bauxite mine', *Transactions of Nonferrous Metals Society of China*, vol. 21, pp. s506-s515.

Western Australian Planning Commission and ICC Infrastructure Coordinating Committee, 2014, *Infrastructure Corridors Issues Paper*, Western Australian Government, Perth.

Wood, Z, Hoffman, G, Wazny, M 2010, 'Finding good paths: applications of least cost caloric path computations', 25th International Conference on Computers and Their Application, CATA-2010, pp. 186–191.

World Bank, 2004, *Averting an Infrastructure Crisis: A Framework for Policy and Action,* Indonesia.

Annexe 2: Project Management And Administration

RESEARCH TEAM

The research project involved collaborative research between The University of Queensland (UQ) through CSRM – SMI, and The Institute Technology Bandung (ITB) through RG-RCIS. The main tasks for each institution are highlighted below.

CSRM acted as an International partner and the lead research team. The main tasks of CSRM included:

1) Managing the research activities and overall budget as highlighted in the head contract
2) Taking the lead in the research implementation and design, including development of the theoretical framework and methodology
3) Having the primary responsibility for research project deliverables
4) Together with ITB researchers, conducting field work in Indonesia and collecting geo-spatial data and other relevant documents
5) Developing GIS progressive modelling for mineral infrastructure planning and supervising ITB in conducting GIS proximity analysis
6) Maintaining relationships with key partners in Indonesia
7) Initiating and participating in project regular meetings by phone or skype

RG-RCIS acted as the Indonesian research collaborator. RG-RCIS researchers have significantly contributed to this collaborative research project. The main tasks of RG-RCIS included:

1) Gaining the support of relevant government agencies and other stakeholders in Indonesia and participating in field work in both case study regions and Jakarta.
2) Liaising and collecting geo-spatial datasets and performing geo-spatial data cleaning together with CSRM researchers
3) Assisting with the development of the geo-database and its analysis in order to create a working GIS to support mineral infrastructure planning
4) Developing the GIS proximity analysis using East Kutai as a case study region
5) Facilitating and conducting any necessary fieldwork in Indonesia including logistics arrangement
6) Participating in regular project meetings by phone and skype
7) Providing critical written and intellectual input into the deliverables

The profile of research team members including their specific institutional affiliations and expertise are provided below. The specific contribution and role of each of the research team members from CSRM and ITB are provided in the Table A2.1. The profile of research team members is provided in Table A2.2 (UQ Team) and Table A2.3 (ITB Team).

Table A2.1 Role of Research Team Members

Name	Role to the research project	Main tasks
UQ (CSRM & CMLR-SMI)		
Prof Saleem Ali	Chief Investigator	Provided overall research guidance and methodological advice
Bernadetta Devi	Research Manager	Managed the research project and deliverables Provided technical expertise on engagement strategies in Indonesia and material contents on research implementation and design
Dr. Alex Lechner	Research Team Member	GIS modelling
Dr. Paul Rogers	Research Team Member	Social research input
Ashlee Schleger	Research Team Member	Reviewing and bench-marking socio-ecological factors
Phil McKenna	Research Team Member	GIS geo-database design and management
ITB (RG-RCIS)		
Professor Miming Miharja	Indonesian Team Leader	Provided guidance on Indonesian infrastructure planning
Dr. Heru Purboyo	Research Team Member	Transportation planning
Dr. Shanty Rachmat	Research Team Member	GIS modelling and the key partner for research management
Lusiana Suwandi	Research Team Member	GIS Assistant
Azis Hakim Sjafruddin	Research Team Member	GIS Assistant

Table A2.1 UQ (CSRM) Team

	Saleem H. Ali is Chair in Sustainable Resource Development and Professor of Politics and International Studies at the University of Queensland, Australia. He is also Adjunct Professor of Environmental Planning at the University of Vermont in the US. Professor Ali's research focuses on environmental conflicts in the extractive industries and how ecological cooperation can promote peace in international relations. He is the author of 4 books including *Treasures of the Earth: Need, Greed and a Sustainable Future*, (published by Yale University Press), and *Environmental Diplomacy* (with Lawrence Susskind, Oxford Univ. Press). Professor Ali was chosen as a Young Global Leader by the World Economic Forum in 2011 and received an Emerging Explorer award from the National Geographic Society in 2010, and has since then also been a member of the IUCN World Commission on Protected Areas. He received his doctorate in Environmental Planning from MIT, a Master's degree in Environmental Studies from Yale University and Bachelor's degree in Chemistry from Tufts University. Professor Ali can be followed on Twitter @saleem_ali
	Bernadetta Devi is a Research Manager at the Centre for Social Responsibility in Mining and also the founder of Bermata Consulting. Her research interests are: extractive industry policy; understanding partnership and collaboration for community development; and evaluating impacts and outcomes of social investments in the mining sector to promote sustainable development outcomes. In conducting and managing her research and consultancy works, she intensively engaged with mining companies, Non-Government Organisations and International agencies. She is currently a member of Netherlands Commission for Environmental Assessment's expert panel to provide advice on tin mining in Indonesia. Bernadetta is a native Indonesian and has extensive public sector experience within Indonesian (provincial) and Queensland governments. She holds a Master of Environmental Management and Development from the Australian National University, Canberra and a Master of Arts in International Development Studies from Chulalongkorn University, Bangkok.

	Dr Alex Lechner is a Landscape Ecologist experienced in applying spatial analysis to natural resource management. He was recently awarded a three year University of Queensland Postdoctoral Research Fellowship with the Centre for Social Responsibility in Mining, focusing on the application GIS to land use planning in mining regions integrating social and ecological factors. Alex has published over 41 peer-reviewed academic articles including 21 international journal articles.
	Dr Paul Rogers is a human geographer by training. His research and teaching interests are focused on community development, indigenous peoples, and the socio-economic impact assessment of resource projects. A major focus of his work at CSRM is on the development of good practice guides and toolkits for the mining and oil and gas industries. He is currently a contributing author to the OECD's forthcoming Due Diligence Guidance for Stakeholder Engagement in the Extractive Industries, and co-lead author of the 2015 update of the International Council on Mining and Metals (ICMM) Indigenous Peoples and Mining Good Practice Guide. Paul has a particular interest in Indonesia, where he conducted research on resettlement and land conflict in the context of large-scale tree crop development projects sponsored by institutions such as the World Bank.
	Ashlee is a Research Analyst at the Centre for Social Responsibility in Mining (CSRM) with a particular focus on Central and South-East Asia. Ashlee has worked in a range of areas including impact and program evaluation, gender, agreement-making, and reviewing social evaluation frameworks to determine the development outcomes of mining projects and their associated investments. Ashlee holds a Masters of Social Science (International, Urban and Environmental Management) from the Royal Melbourne Institute of Technology (RMIT) University and a Bachelor of Regional and Town Planning (Honours) from the University of Queensland.

	Phill is a GIS specialist in his role as Research Officer with the CMLR at the University of Queensland. Phill completed a Bachelor of Forest Science Degree at The University of Melbourne and spent 7 years working with the soil & water group in the Victorian Department of Sustainability and Environment. Following a four year stint as a touring musician, Phill joined the team in 2007 and manages various ecological research projects associated with mine site rehabilitation in Australia and overseas.

Table A2.2 ITB (RG-RCIS) Research Team

	Miming Miharja was granted the PhD degree on June 2009 from Faculty of Spatial Sciences Rijkuniversiteit Groningen, the Netherlands. His research interests are Transportation planning, specifically in policy development; inter local government collaboration transportation planning or metropolitan transport planning. Currently, he is a lecturer and researcher at the research group of regional and city infrastructure system, ITB.
	Heru Purboyo was granted the PhD degree on November 1994 from Urbanisme et Amenagement, de l'Universite de Paris VIII, Paris, France. His research interests are in Urban Geography and infrastructure planning, specifically in the associated between Travel behavior of Suburbs Population with Urban Facilities Distribution, Communal Urban Public Services. Currently, he is a lecturer and researcher at the research group of regional and city infrastructure system, ITB.
	Shanty Rachmat was granted the PhD degree on May 2014 from School of Design, Construction and Planning, University of Florida, US. Currently, she is a junior lecturer and researcher at the research group of regional and city infrastructure system, ITB. Her research interests are infrastructure planning and policy, specifically in transportation demand management, the interaction of travel behavior and land use, the community involvement on infrastructure and transportation planning.

	Lusiana Suwandi was born in Sukabumi on April 5th 1992. Her major is Urban and Regional Planning. She graduated from Institut Teknologi Bandung in March 2015. Her interests include GIS application for urban planning and infrastructure planning subjects. She's aspiring to pursue a master's degree in GIS for Urban Planning.
	Azis Hakim Sjafruddin was born in Copenhagen, Denmark, on January 22nd 1992. He graduated from Urban and Regional Planning, Institut Teknologi Bandung in 2014. He is interested in transportation planning and GIS related researches. He wishes to become a transportation planner in the future.
	Desiree Kipuw was granted her master degree on July 2009, from School of Architecture, planning and policy development, ITB. Her research interests include regional planning and infrastructure planning and policy. Currently, she is a researcher at the research group of regional and city infrastructure system, ITB.

GENERAL ISSUES

Management of Activity

The research was led by CSRM with support received from RG-RCIS. Roles and responsibilities were distributed based on the strengths of each institution as described in the Section 1.5. In managing the research activities, key contacts from each institution namely Bernadetta Devi (CSRM) and Dr. Shanty Rachmat (ITB) were appointed to manage and coordinate research activities for both teams. To maintain good internal communication, regular phone and Skype meetings were held. For data and information coordination and sharing amongst both teams, an online information exchange platform for both research teams was created.

Internal Quality Assurance

The major impediment that was faced by both research teams related to the geo-spatial data. The research relied on the geo-spatial data that the teams collected from various sources of government agencies and companies. We found that the geo-spatial data required for the research are in-consistent in their quality and availability. Some specific issues that the teams faced include:

- Coordinate systems used in the current maps produced by various government agencies, private companies and other institutions are inconsistent
- The accuracy of the available maps is questionable with data coverage in shape file layers being incomplete and inconsistent for the case study regions
- Meta-data information such as the source of the data, institution that created the maps, and year when the map was built is not available.

These limitations may prevent the accuracy of our GIS analysis and modeling in both case studies of East Kutai and South Konawe regencies. However, it does not significantly affect the intended objectives of the research as the main focus of the research is to suggest a methodology and a workable GIS tool that considers socio-ecological factors in mineral infrastructure planning. Suggestions and recommendations on how our GIS tools can be further developed and improved are also provided in this report.

Another issue that may impact on the quality of this research is an unequal treatment of the case study regions due to accessibility issues in the case study regions. Access to case study sites has been a challenge for the research team. There are no direct flights to both case study locations and one site can only be accessed by using the company airline. Consequently, the research team spent extra time travelling between locations. Although this was not a major issue in conducting our research, some field plans were adjusted to accommodate the transport availability. Subsequently, we had a greater engagement with key stakeholders in South East Sulawesi Province (South Konawe case study) in comparison with East Kutai Regency.

Budget Expended

The head agreement of the sub-consultancy for the research was done between UQ and SMEC International on behalf of the Australian Government. UQ then arranged a further sub-consultancy arrangement with RG-RCIS through "*Lembaga Afiliasi Penelitian dan Industri, Institut Teknologi Bandung*" to conduct this collaborative research. The budget has been spent as provided for in the sub-consultancy agreements. Details of budget expenditure are provided to the client (SMEC International) separately in the financial report of the project.

Partnership's Responses to Mid-Term and Draft Final Report

Both research teams have collaboratively answered the main input provided in the mid-term report and draft final report. The main feedback received for the mid-term report concerned the clarity of the intended GIS tools for mineral infrastructure planning. Issues raised and the team's responses for the mid-term report are summarised in Table A2.4.

Table A2.4 Feedback Received for the Mid-Term Report and Collaborative Team Responses

Feedback received (October & November 2015)	Team Responses in the remaining project life (November – May 2015)
The translation of socio-ecological factors gathered from literature (benchmarks) into a subset of preferred and workable factors	The research teams did joint field work to investigate how key national and regional respondents value and prioritise the socio-ecological factors. The team also collected the geo-spatial data during the field visits. These have been analysed, evaluated and triangulated. Both teams have been working together with shared responsibilities: ITB analysed the East Kutai case study and CSRM focused on the South Konawe case study.
Actual data that can be used in the GIS analysis and modelling for the case study regions	Actual data were collected by both research teams. Those data have been used to inform the GIS modelling techniques developed by both research teams. ITB developed the **evaluative-overlay method** for the East Kutai case study and CSRM developed the **least-cost path modelling** for the South Konawe case study.
Descriptions of the main users of the research	The teams agreed that the users of the research findings will be: **Governments** - as they have the authority for major project approvals. **Universities** - further research needs to be done under this research theme. Researchers from both teams will further develop the research tools. ITB researchers play an important role in influencing infrastructure planning and policies in Indonesia **Companies** – can utilise the research findings to plan their infrastructure either directly associated with their mining activities or for community infrastructure

The research team further received feedback and suggestions for the draft final report in August 2015 following the review conducted by IndII personnel and two external peer reviewers. The UQ and ITB research teams have worked collaboratively to address the feedback and make necessary adjustments as shown in this final report.

Annexe 3: Stakeholder Survey – Weighting Questionnaire For Socio-Ecological Factors

Statements	1 Extremely not important	2 Not important	3 Don't know	4 important	5 Extremely important
Community factors					
Population settlements					
Community agricultural land and activities					
Community forestry and access to forest					
Community fishing areas					
Artisanal mining					
Social infrastructure (schools, hospital, etc)					
Considering *masyarakat adat* population and areas					
Cultural heritage significance or purpose					
Follow up qualitative questions: 1. Do you have additional factors to add? 2. Can you rank the 3 factors that are really important for you? Why? 3. If there will be infrastructure development, what do you think is reasonable and appropriate buffer zone or necessary distance to the factors listed above? Why? Can you support your answer with data/law/personal observations?					
Water habitat and resources					
Existing water bodies (e.g. rivers or streams, wetlands, lakes, coastal areas, floodplains, ground water system)					
Aquatic (marine and freshwater) resources, species and habitat					
Community wells					
Follow up qualitative questions: 1. Do you have additional factors to add? 2. Can you rank the 3 factors that are really important for you? Why? 3. If there will be infrastructure development, what do you think is reasonable and appropriate buffer zone or necessary distance to the factors listed above? Why? Can you support your answer with data/law/personal observations?					
Conservation areas					
National parks or protected areas					
Specific ecological zones/habitat types (e.g. Orang Utan habitat)					
Areas of high biological diversity					
Areas of threatened or endangered species					
Habitat corridors or linkages between areas and remnant vegetation					

Follow up qualitative questions: 1. Do you have additional factors to add? 2. Can you rank the 3 factors that are really important for you? Why? 3. If there will be infrastructure development, what do you think is reasonable and appropriate buffer zone or necessary distance to the factors listed above? Why? Can you support your answer with data/law/personal observations?					
Statements	1 Extremely not important	2 Not important	3 Don't know	4 important	5 Extremely important
Industrial activities					
Operating mines and mines leases					
Oil Palm					
Industrial estate					
Cocoa plantation					
Fishing zones					
Follow up qualitative questions: 1. Do you have additional factors to add? 2. Can you rank the 3 factors that are really important for you? Why? 3. If there will be infrastructure development, what do you think is reasonable and appropriate buffer zone or necessary distance to the factors listed above? Why? Can you support your answer with data/law/personal observations?					
Existing infrastructure					
Sea - Ports (national, provincial and local)					
Roads and bridges (national, provincial and local)					
Airports					
Railways					
Follow up qualitative questions: 1. Do you have additional factors to add? 2. Can you rank the 3 factors that are really important for you? Why? 3. If there will be infrastructure development, what do you think is reasonable and appropriate buffer zone or necessary distance to the factors listed above? Why? Can you support your answer with data/law/personal observations?					

Annexe 4: GIS Evaluation Of Compatibility Of Mining And Road Infrastructure With Socio-Ecological Factors

SUMMARY

In this project, the research team applied GIS overlay and proximity analysis to evaluate the suitability of existing mining and road infrastructure with socio-ecological factors in the study case area, East Kutai Regency. Through interviews with the representatives of governments and companies in East Kutai, we found that respondents believed there was a lack of a structured method for infrastructure planning; rather there was a perception that infrastructure was built in an ad-hoc and reactionary manner without the use of a well-defined methodology capable of taking into account the social and ecological systems in the landscape. Subsequently, we evaluated current practices by analysing the compatibility between road infrastructure and socio-ecological factors in a minerals-rich region i.e. East Kutai Regency. In this exercise, we performed GIS overlay and proximity buffer analysis for existing road networks at three road hierarchies (national, provincial and local roads) in East Kutai Regency.

We found that the definition of mineral infrastructure is problematic in East Kutai Regency as the region was first known as a mining town. In this case, infrastructure was specifically built to serve mining activities. As the town developed and opened up for new settlements and other economic activities, we observed that current mineral infrastructure also served for public and other economic activities. In our analysis, we tried to be consistent in analysing national, provincial and local roads. However, due to data availability, we did not analyse down to the level of local roads.

The aim of the analysis provided in this annexe is to describe an initial process for investigating the geographic proximity of the existing road networks in East Kutai to selected social and ecological factors (e.g. community forests) in order to determine the extent to which such factors are considered in current infrastructure planning.

GIS BASED EVALUATIVE OVERLAY AND PROXIMITY METHOD

The research team applied GIS overlay and proximity buffer analysis methods to evaluate the suitability of existing mining and road infrastructure by incorporating selected socio-ecological factors for the case study region of East Kutai Regency. The suitability method is commonly used by planners for considering the interplay of location, development actions, and environmental factors (Collins M., Steiner F., Rushman M. J., 2001). It allows planners to gain better understanding about the interactions between these factors which can inform necessary policy and possible actions in a more integrated way.

Historically, there are five phases in the evolution of the suitability method: i) an early hand-drawn and manual map filtering process; ii) development in the literature; iii) computer-assisted overlay mapping; iv) redefinition of spatial data and multi-criteria evaluation; and v) the replication of expert knowledge in the current state process (Collins M., et al., 2001, p.612). Within the use of suitability analysis, two types of analysis are discussed such as a *site selection* problem and a *site search* problem (Malczewski, 2004). The site selection analysis is mostly to rank possible suitability sites based on a list of selected indicators. The site search problem analysis is used when indicators are not firmly defined and the boundary of targeted sites is well-defined and becomes the focus of the analysis (Malczewski, 2004).

In the current application of suitability analysis, GIS assisted overlay and buffer analysis methods is commonly utilised in several fields such as urban planning, regional planning and environmental planning (Malczewski, 2004); and with specific applications in land-use allocation, environmental impacts, or site selection both for public and private infrastructure (Collins M., et al., 2001). In the mining sector, suitability evaluation has been promoted in particular for mined land reclamation and rehabilitation (Wang, Liu, and Zhang, 2011).

In this research, we applied the overlay and proximity buffer analysis methods to evaluate the compatibility between mineral infrastructure and socio-ecological factors as identified in Chapter 3. The aims of performing these methods are to investigate: whether preferences held by the stakeholders reflect how road infrastructure is actually developed; and whether mining operations are in conflict with social-ecological preferences. This compatibility analysis is a useful and important first step in understanding the relationship between current development and values held by the respondents. Furthermore, it helps infrastructure planners to identify whether infrastructure planning has contributed to sustainable development by effectively incorporating social-ecological values.

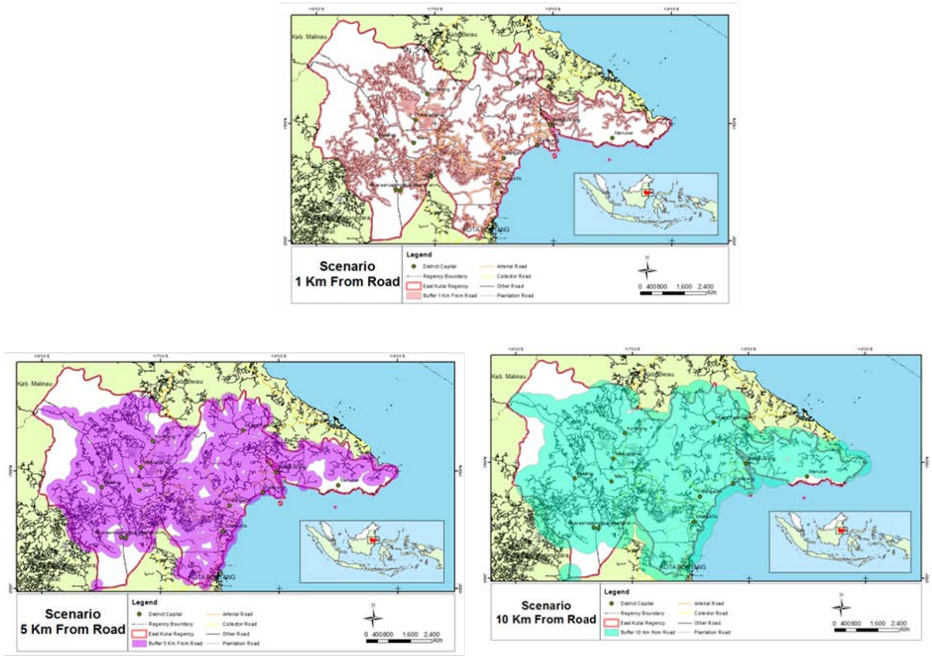
The analysis that we conducted in this research is intended to represent an initial process of evaluating the existing social and ecological landscape that has been impacted by the existing mineral infrastructure, in this case, road networks within four scenarios as described above.

SCENARIOS

For the overlay and proximity analysis, we defined four different buffer-scenarios as presented in Figure A4.1 and they include:

- **Scenario 1** : 1 kilometre buffer from existing road networks
- **Scenario 2** : 5 kilometre buffer from existing road networks
- **Scenario 3** : 10 kilometre buffer from the existing road networks.

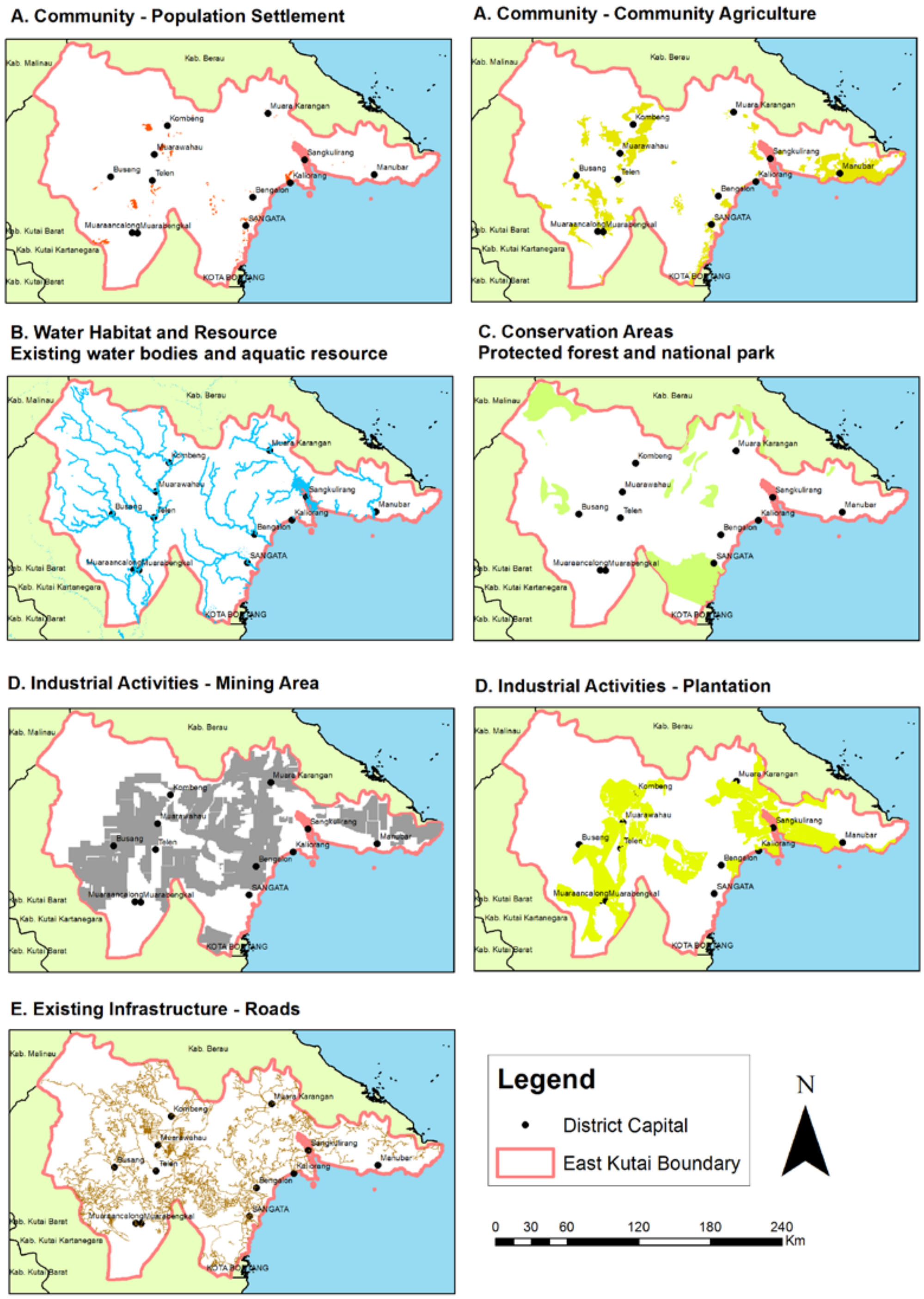
Figure A4.1 The Scenarios for Overlay and Buffer Analysis Methods



For the scenarios 1 to 3, we characterised the social and ecological values that correspond to the location of infrastructure and applied three different distances (1, 5 and 10 kilometres) from the road networks as the buffers (see Figure A4.1).

Once we delineated our scenarios, we applied the overlay and buffer analysis with relevant and measurable socio-ecological factors and sub-factors for the East Kutai case study as identified in Chapter 3. It should be noted that we did not conduct primary data collection; the spatial data used in this research were collected from various sources such as government agencies, companies and other publicly available data. Factors used in the analysis include: population settlement; community agriculture; existing water bodies and aquatic resources; protected forest and national park; mining area; and plantation (cocoa plantation) as presented in Figure A4.2.

Figure A4.2 Available Factors from East Kutai Regency Case Study Utilised for The Evaluative Overlay Analysis



FINDINGS

Table A4.1 shows the total areas of factors against the three scenarios. The total areas for each factor are described in percentages. It shows the intersect area between the buffer area of each scenario and each factor. The overall findings of our analysis against socio-ecological factors are summarised below:

- The percentage of community factors (settlements and agricultural areas) is relatively small (or less than 15%) within a 1 kilometre and 5 kilometre buffer from provincial roads.
- There is a higher percentage of all factors within a 1 kilometre and 5 kilometre buffer from national roads, when compared with provincial roads.
- The highest percentage of area that is covered by 1 kilometre buffer from national road is community settlement (13%)
- The total percentage of area for operating mines and mines leases within 1 km and 5 km buffer of national road is 2% and 10% respectively.

Detailed descriptions of these factors and sub-factors are further described below.

COMMUNITY FACTORS

A. Population Settlements

Our findings show that: the percentage of population settlement within 1 km, 5 km and 10 km buffer of national roads are 13%; 28%; and 41% respectively. The percentages of population settlements with similar buffer areas for provincial roads are 0%; 0%; and 7%. Although coverage for local or regency roads is almost all-covered, other scenarios show that road infrastructures (and part of them are mineral infrastructure) support only a small area of population settlements. Figure A4.3 shows the coverage area for each scenario.

B. Community Agricultural land and activities

The percentage of community agricultural land activities within 1 km, 5 km and 10 km buffer of national road are 4%; 15%; and 24 % respectively. The percentages of community agricultural land activities with similar buffer areas for provincial road are 1%; 4%; and 6% respectively. Although coverage for local or regency roads is almost all-covered, other scenarios show that road infrastructures (and part of them are mineral infrastructure) support only a small area of community agricultural land activities. Figure A4.5 shows the coverage area for each scenario.

C. Community Forestry and access to forest

The percentage of community forestry and access to forest within 1 km, 5 km and 10 km buffer of national road is 1%; 6%; and 12% respectively. The percentages of community forestry and access to forest with similar buffer areas for provincial roads are 1%; 4%; and 7% respectively. Although local or regency roads are almost all-covered, other scenarios show that road infrastructure (and parts of them are mineral infrastructure) support only a small area of community forestry and access to forest. Figure A3.6 shows the coverage area for each scenario.

WATER HABITAT AND RESOURCES (RIVER / EXISTING WATER BODIES)

For the water habitat and resources scenario, a buffer area of 25 meters from the polyline river data was used. The percentage of river buffer area within 1 km, 5 km and 10 km buffer of national roads are 2%; 8%; and 17% respectively. The percentages of river buffer area with similar buffer areas for provincial roads are 0%; 4%; and 7%. Figure A4.7 shows the coverage area for each scenario.

CONSERVATION AREAS (PROTECTED FOREST AND NATIONAL PARK)

The percentage of national park and protected forest area within the 1 km, 5 km and 10 km buffer of national roads are 3%; 153%; and 29% respectively. The percentages of national park and protected forest with similar buffer areas for provincial roads are 0%; 0%; and 2%. Figure A4.8 shows the coverage area for each scenario.

INDUSTRIAL ACTIVITIES

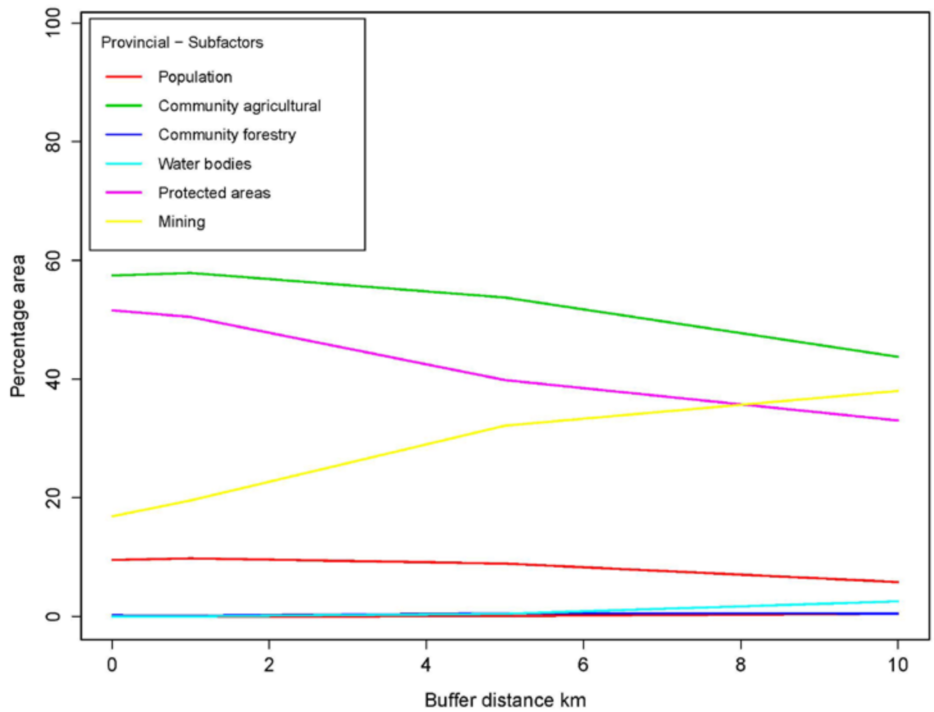
A. Operating Mines and Mines Leases

The percentage of operating mines and mines leases within 1 km, 5 km and 10 km buffer of national road are 2%; 10%; and 20% respectively. The percentages of operating mines and mines leases with similar buffer areas for provincial roads are 1%; 4%; and7% respectively. Although coverage for local or regency roads is almost all-covered, other scenarios show that road infrastructure (including mineral infrastructure) support only a small area of operating mines and mines leases. Figure A4.9 shows the coverage area for each scenario.

B. Cocoa Plantation

Data for plantations (used as a proxy for cocoa plantations) was used in these scenarios. The percentages of cocoa plantation within 1 km, 5 km and 10 km buffer of national roads are 3%; 15%; and 28% respectively. The percentages of cocoa plantation with similar buffer areas for provincial roads are 1%; 6%; and 15% respectively. Although almost all local and regency roads are covered, other scenarios show that road infrastructure (including mineral infrastructure) supports only a small area of cocoa plantation. Figure A4.10 shows the coverage area for each scenario.

Figure A4.3 Comparison of Factor Area Percentage within Buffer Areas to Buffer Distances.



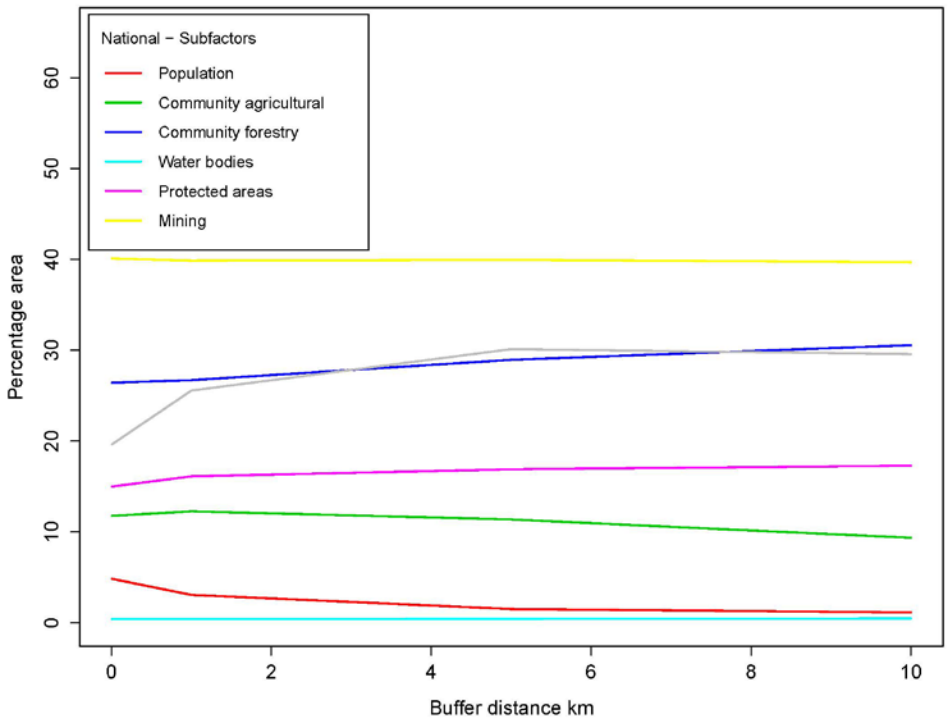


Table A4.1 The Summary of Total Areas Based On Scenarios

Factors	Total Area (Km2)	National Road			Province Road			Local Road		
		Sc-2 1km	Sc-3 5km	Sc-4 10km	Sc-2 1km	Sc-3 5km	Sc-4 10km	Sc-2 1km	Sc-3 5km	Sc-4 10km
		Area (Km2)	Area (Km2)	Area (Km2)	Area (Km2)	Area (Km2)	Area (Km2)	Area (Km2)	Area (Km2)	Area (Km2)
A. Community factors										
Population settlements	191.72	24.19	53.81	77.90	-	0.81	12.80	149.71	191.72	191.72
Community agricultural land and activities	2,669.02	97.01	406.86	647.18	26.17	118.21	165.83	1,290.27	2,115.30	2,485.88
Community forestry and access to forest	17,227.45	211.29	1,036.18	2,115.20	154.81	712.88	1,252.20	6,027.58	12,978.26	15,283.68
B. Water habitat and resources										
Existing water bodies (e.g. rivers or streams, wetlands, lakes, coastal areas, floodplains, ground water system)	193.50	3.20	14.90	32.40	0.35	7.00	13.60	65.30	152.99	172.40
C. Conservation areas										
National parks or protected areas	2,020.99	127.50	604.60	1,196.20	-	-	50.40	371.60	1,288.90	1,952.40
D. Industrial activities										
Operating mines and mines leases	13,709.76	315.49	1,430.62	2,747.39	134.94	528.31	945.22	6,987.34	12,921.65	13,701.63
Cocoa plantation	7,347.79	202.21	1,078.09	2,047.34	52.28	426.44	1,087.92	3,237.72	6,639.10	7,091.36

Figure A4.4 The Overlay of Community Factors (Population Settlements) and Scenarios

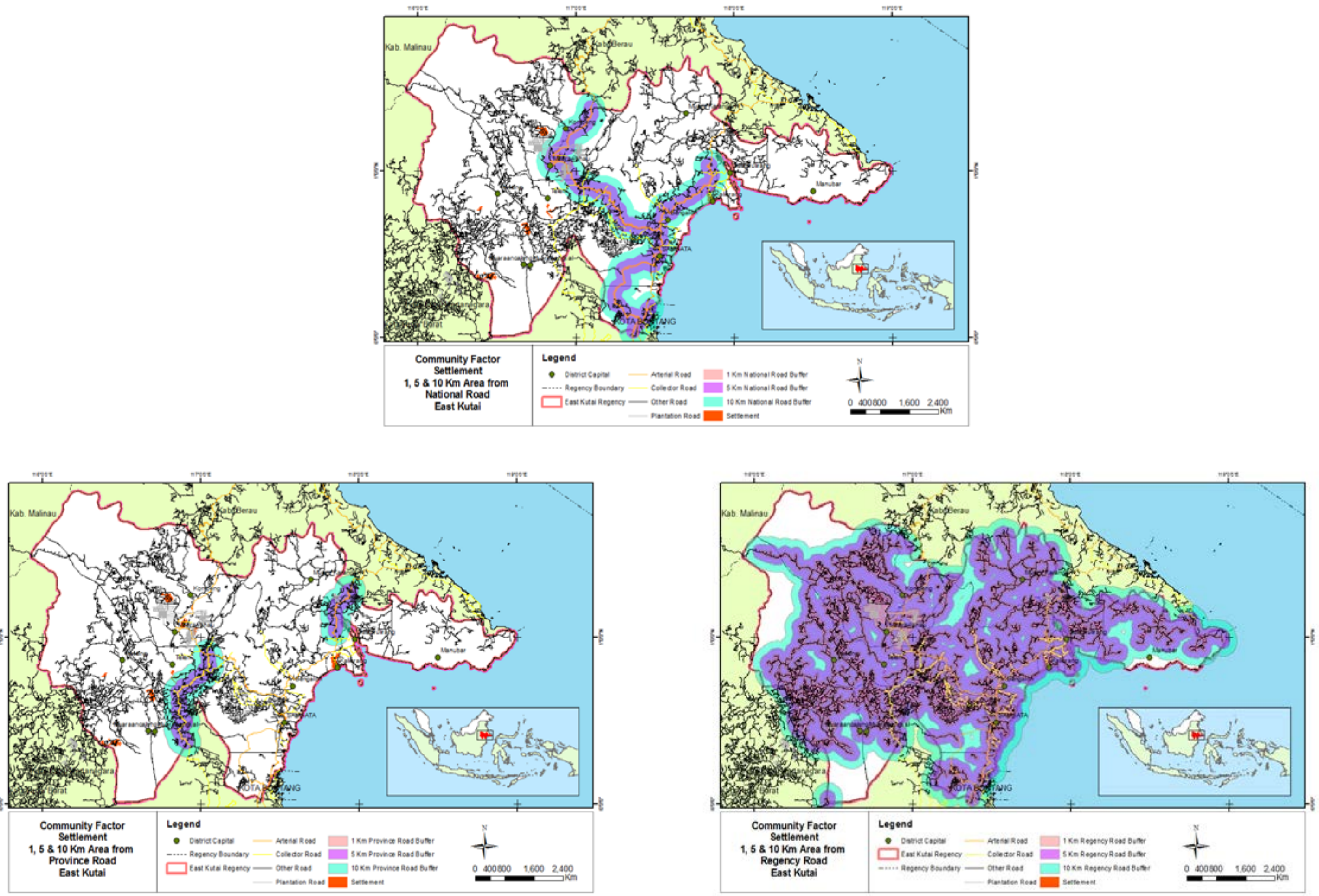


Figure A4.5 The Overlay of Community Factors (Community Agriculture) and Scenarios

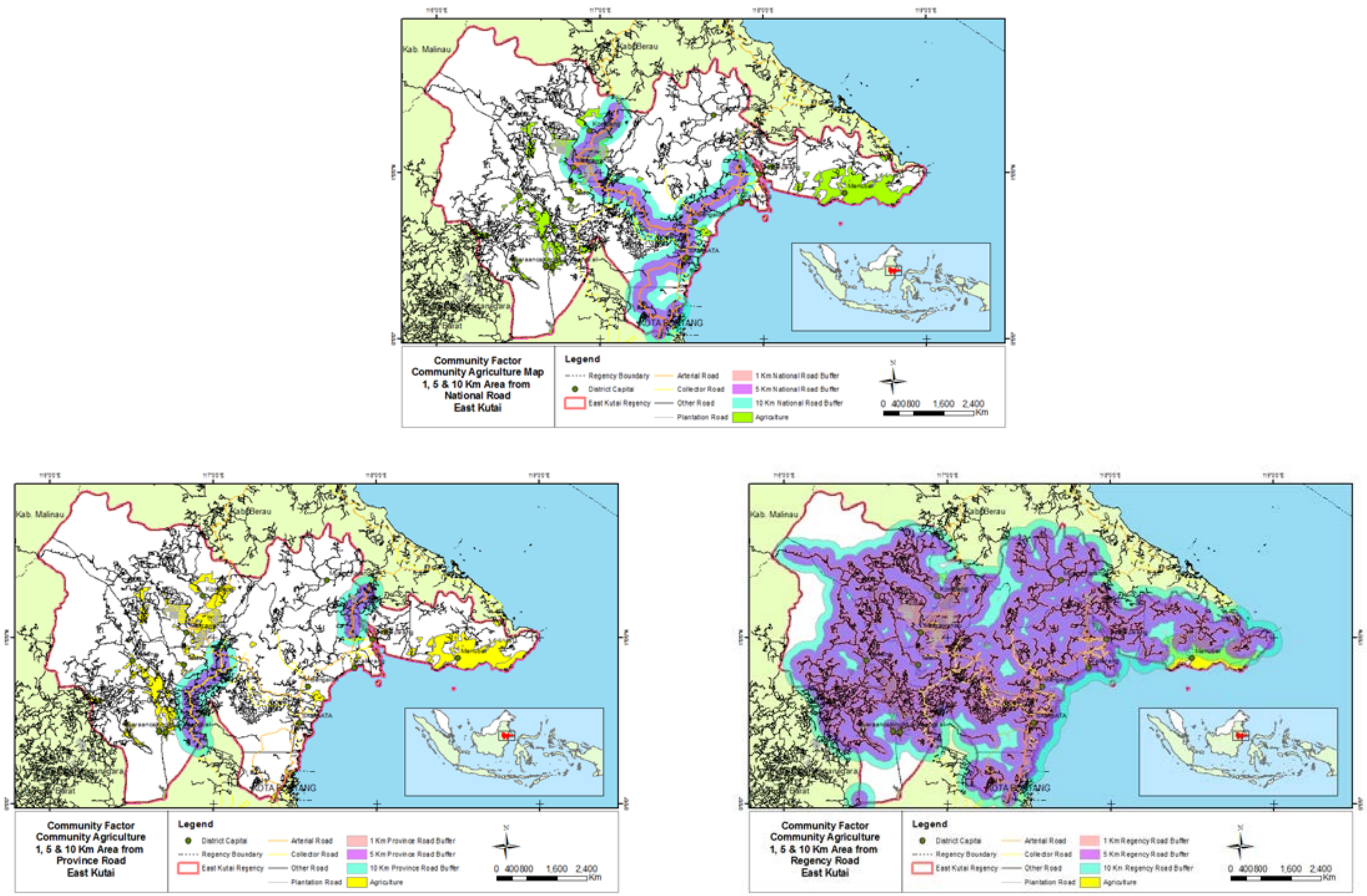
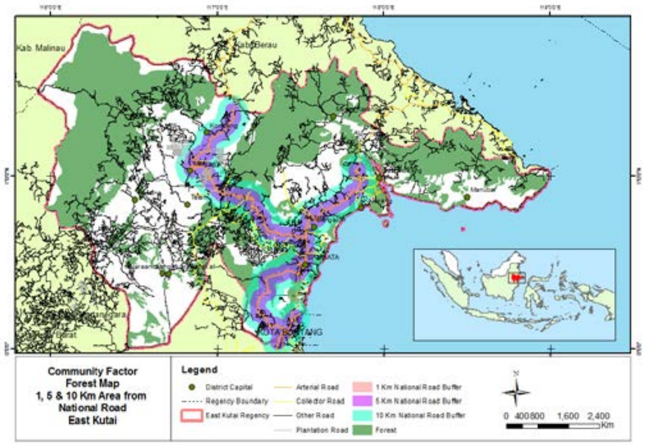
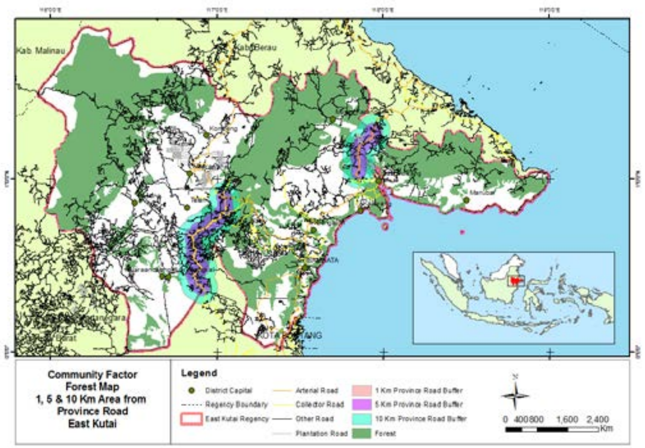


Figure A4.6 The Overlay of Community Factors (Community Forest) and Scenarios





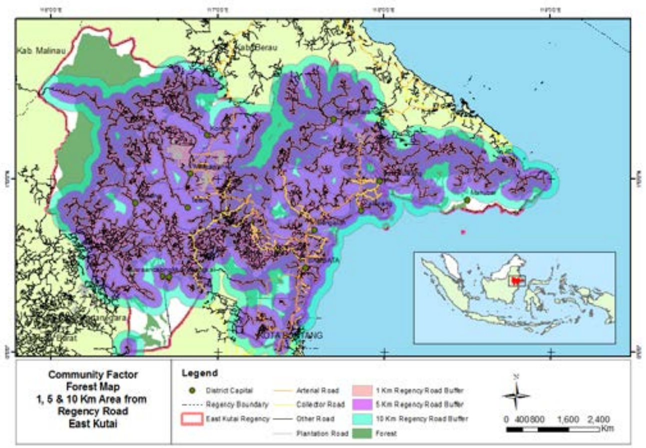


Figure A4.7 The Overlay of Water Habitat and Resource Factor and Scenarios

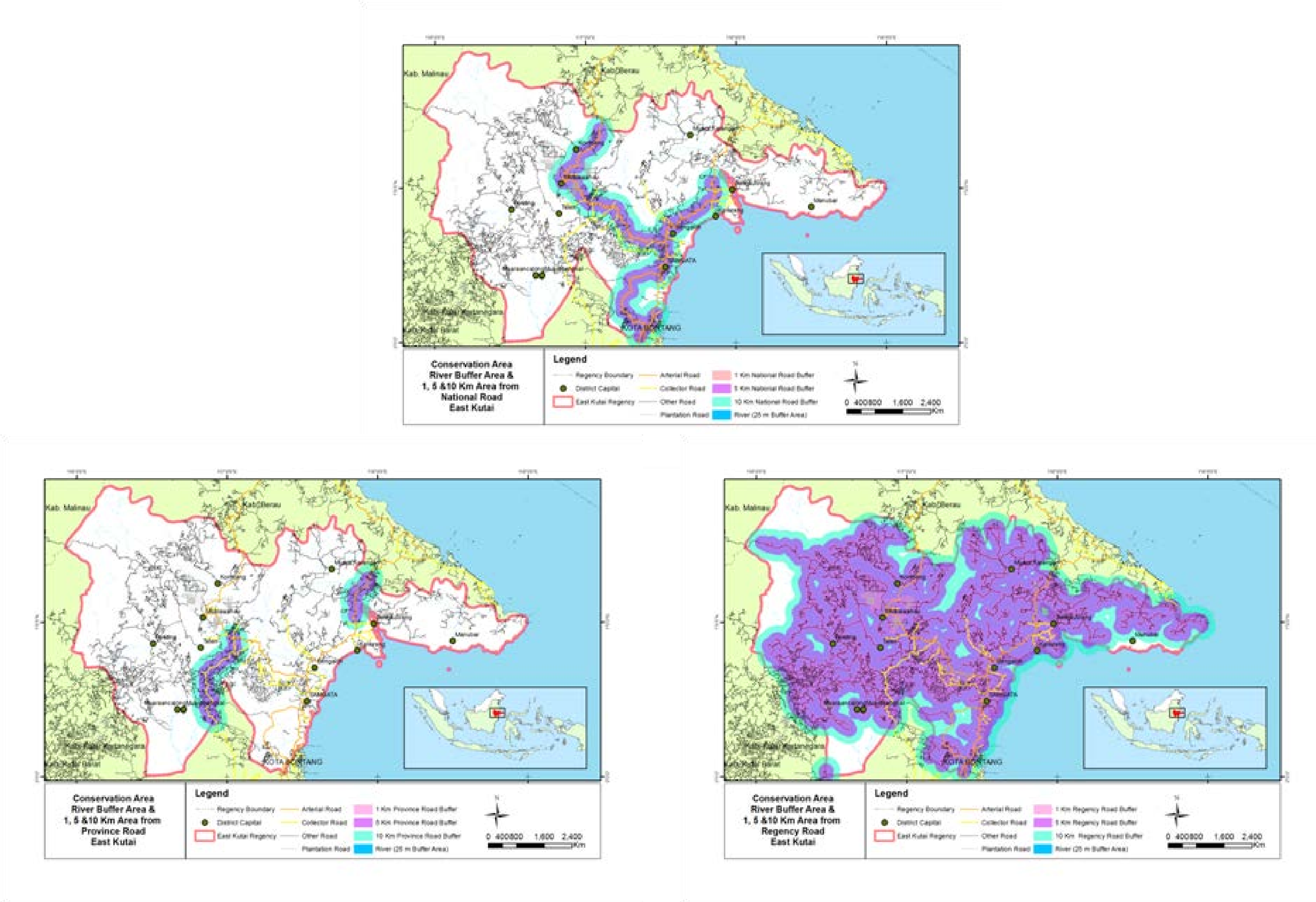


Figure A4.8 The Overlay of Conservation Area Factor and Scenarios

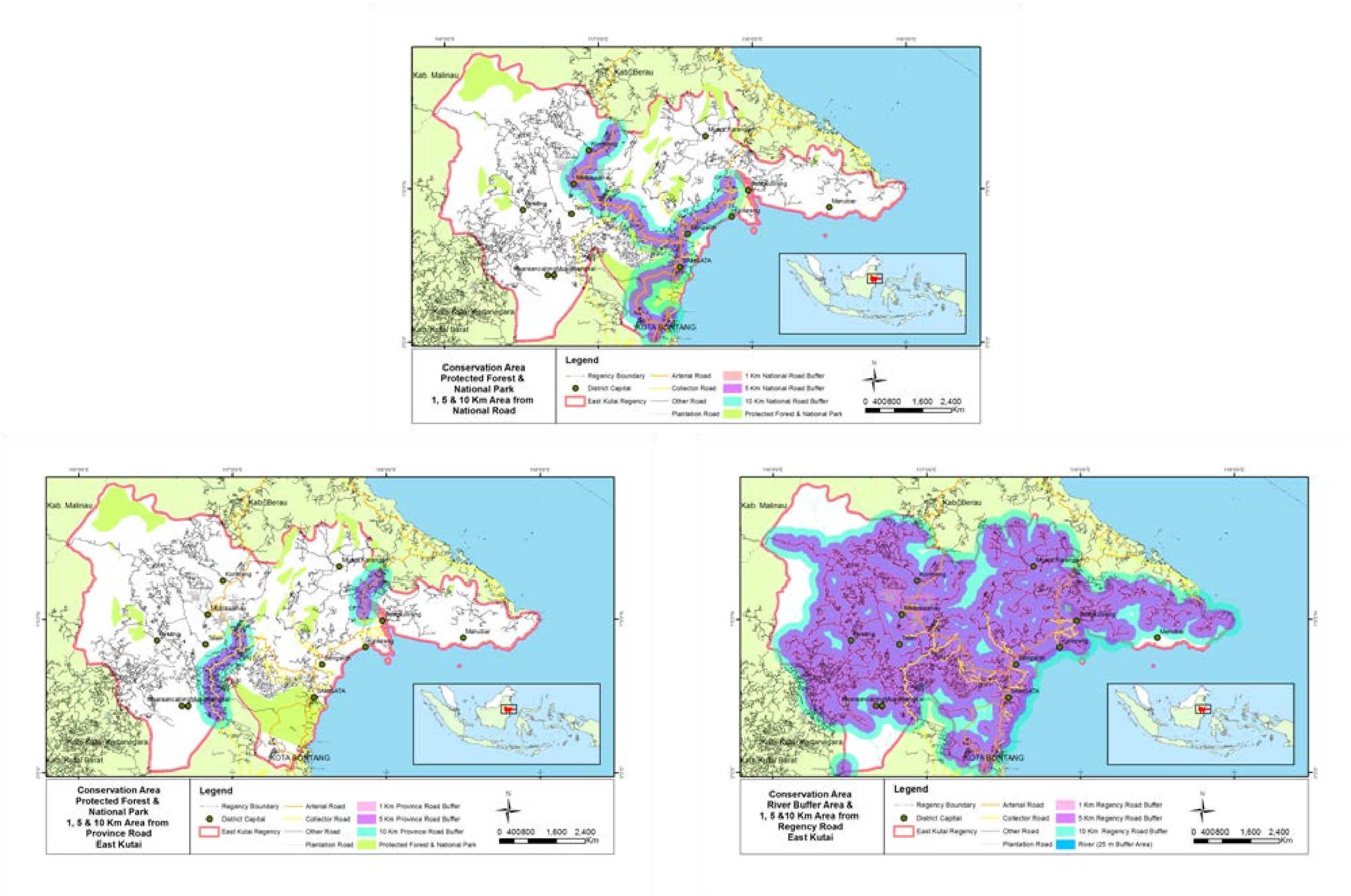


Figure A4.9 The Overlay of Industrial Activities (Mining Area) Factor and Scenarios

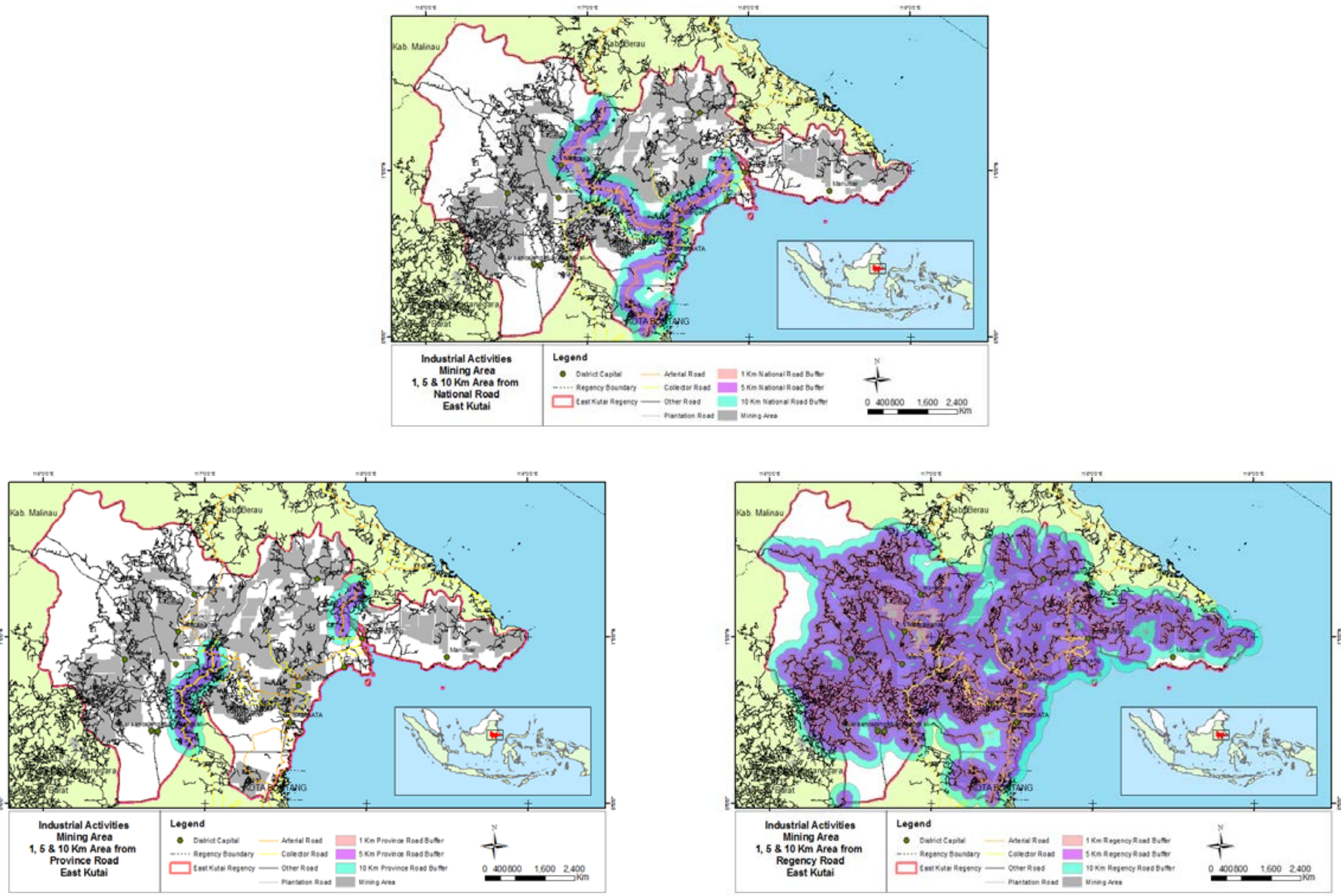
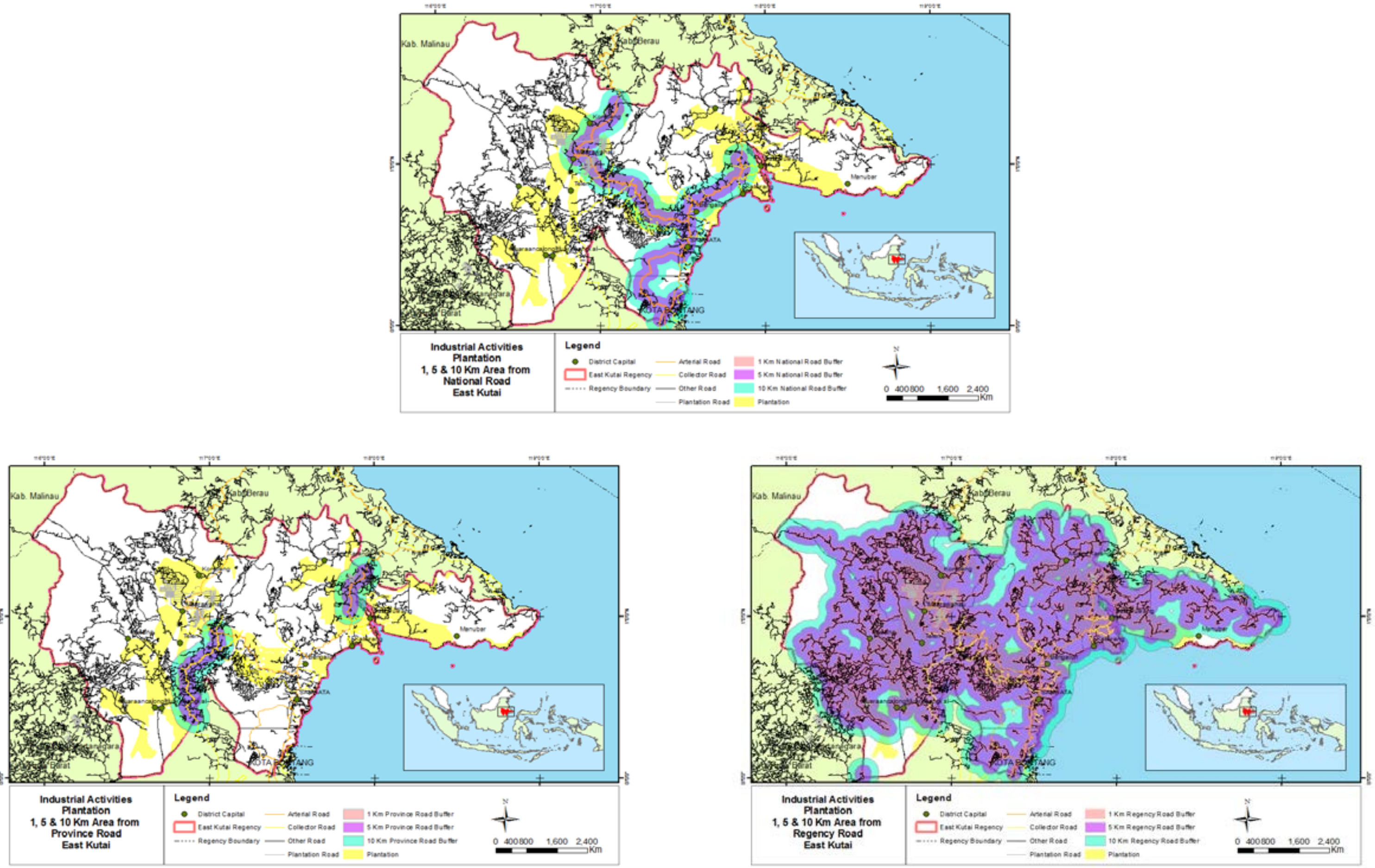


Figure A4.10 The Overlay of Plantation Factor and Scenarios



DISCUSSION

Based on the findings presented above, the following points can be drawn:

1. We may infer two different arguments about the coverage for community factors (settlement, community agricultural land). First, national and provincial road networks do not cover community settlements, a point illustrated by the low percentage of the community area within the established buffer area. Few areas are covered by road infrastructure, especially provincial road. Communities still experience the lack of access because they main rely on local roads. Second, the development of mineral infrastructure is within the appropriate locations of company mining leases. Subsequently, the road networks are located far from the community which can prevent conflicts between community and mining company on the road (or other mineral infrastructures) access.
2. The development of mineral infrastructure nearby community forestry areas, water habitat, conversion area, and plantation area can be a driver of land use conversion. The large-mining company should be cautious about the existence of conservation areas. Also, both government and mining companies need to consider the limitation of area (in relation to conservation area) when they want to develop mineral infrastructures surrounding the ring-1 area.
3. Low percentages for water habitat and conservation area within the 1km, 5km buffers for national and provincial roads show that the development of mineral infrastructure has largely avoided conservation areas. Additionally, very small percentages of provincial road's buffers confirm the argument that few areas have been covered by road infrastructure.
4. In developing mineral infrastructure, government and mining company can work in partnership to provide regional infrastructure and work collaboratively for road maintenance. Key respondents in East Kutai Regency mentioned that a large-mining company has contributed to the building of regional roads under its CSR program and transferred these as national roads. The roads are a shared-use for public and industrial purposes (e.g. other mining operations in the region). Current intensive uses from multiple mining activities have created tensions amongst users, in particular over maintaining the quality of the roads. Meanwhile, the responsible government has limited financial capacity for these roads' maintenance. In addition, co-sharing and multiple-use of roads should come with a careful consideration of different motives, roles and responsibilities of each party to promote long term mutual benefits. In this case, the advocacy and policy development on mineral infrastructure development should be established in advance and among related stakeholders, including small-scale mining companies who also use the mineral infrastructure.
5. Land use conversion is one of the potential impacts of mineral infrastructure development. Strict policy about this conversion needs to be implemented not only for mineral infrastructure development but also in anticipation of community settlement. Also, during our fieldwork in October 2014, we

observed the emergence of new settlement areas within the proximity of newly built roads that are adjacent to conservation areas.

6. We did the analysis based on readily-available data, especially to select socio-ecological factors for this analysis. In our literature review and formulation of factors, we identified some factors for which data is not available (e.g. different types of plantations). This might have limited our findings and analysis as we made a number of assumptions/inferences. For future research, these assumptions should be minimised.

The analysis described in this section provides a useful example on how GIS methods can be used to identify the suitability of infrastructure and mining. Our analysis found little conflict between mines and existing road networks indicating that the planning process is to some degree addressing the social-ecological values held by stakeholders either by luck or by design. However, this analysis did not look at historic land uses to investigate land-use change overtime (e.g. forest clearing). Furthermore, the uncertainty associated with the spatial data and social survey methods mean that the results of the analysis should be treated as preliminary findings.

Annexe 5: Instructions and Python Script

Infrastructure processing instructions

Required scripts:

Cost-surface processing.py

Node processing.py

https://github.com/AlexLechner/Infrastructure-network-processing-tool

Processing steps:

Step 1. Create data CSV table of subfactor weightings

Step 2. Create cost-surface

Step 3. Create node layers

Step 4. Running Graphab

Step 1. Create data CSV table of subfactor weightings

Present the data and weightings describing the subfactors in a 3 column table similar to below (**data CSV**). Where the first column is the file path and the second and 3rd column describes the weightings.

	A	B	C
1	filename	Cost	Cost_weighted
2	A_Community\Community_Ag.shp	0.11	0.44
3	A_Community\Population_settlements.shp	0.09	0.37
4	B_Water\Water_bodies.shp	-0.29	-0.44
5	B_Water\Water_bodies.shp	-0.26	-0.39
6	C_Conservation\Protected_Areas.shp	-0.16	-0.2
7	C_Conservation\Protected_Areas.shp	-0.14	-0.17
8	C_Conservation\Protected_Areas.shp	-0.15	-0.19
9	C_Conservation\Protected_Areas.shp	-0.15	-0.19
10	D_Industrial\mining_permit.shp	0.14	0.24
11	D_Industrial\Production_Forest.shp	0.09	0.15
12	D_Industrial\Plantation_Crop.shp	0.1	0.16
13	E_Infra\Ports.shp	0.26	0.26
14	E_Infra\Airport.shp	-0.28	-0.28
15	E_Infra\Roads.shp	0.21	0.21

Step 2. Create cost-surface

Run “Cost-surface processing.py”

This script does the following:

1. Converts a contour layer into a raster slope layer for a specific pixel size
2. Makes a list of the filenames described by **data CSV**
3. Clips and converts the original shapefile
4. Converts the shapefile to raster for a specified pixel size
5. Weights the subfactor layers and topographic layers
6. Combines all the layers
7. Exports the layer as a .tif.

Step 3. Create node layers

Run “Node processing.py”

1. Converts shapefiles into raster files using the cost-surface as a template to ensure the same number of cells, alignment, and cell size.
2. Exports the layer as a .tif

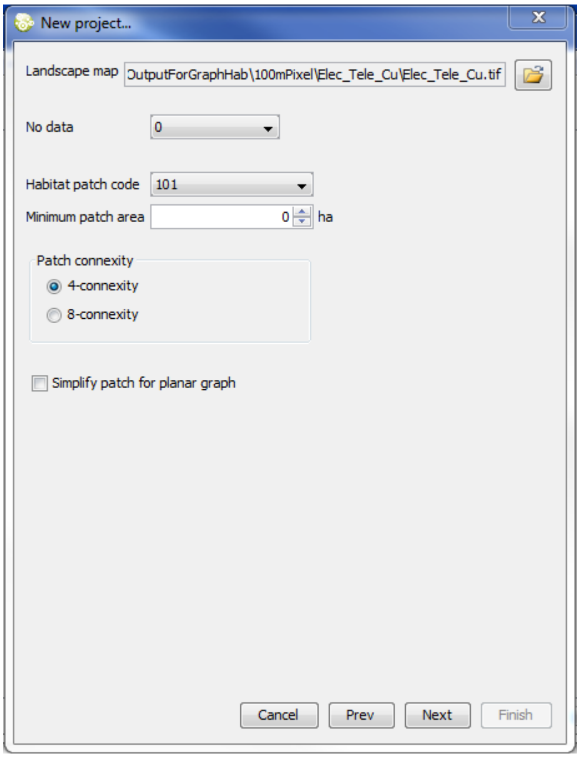
Step 4. Running Graphab

The following diagrams illustrates how to process the node layers and the cost-surface in the Graphab software.

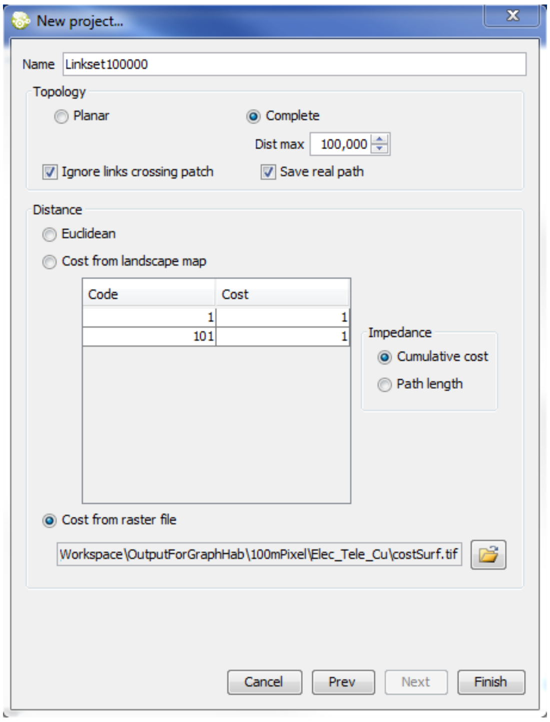
The software can be downloaded from the following website and includes are detailed user manual.

http://thema.univ-fcomte.fr/productions/graphab/

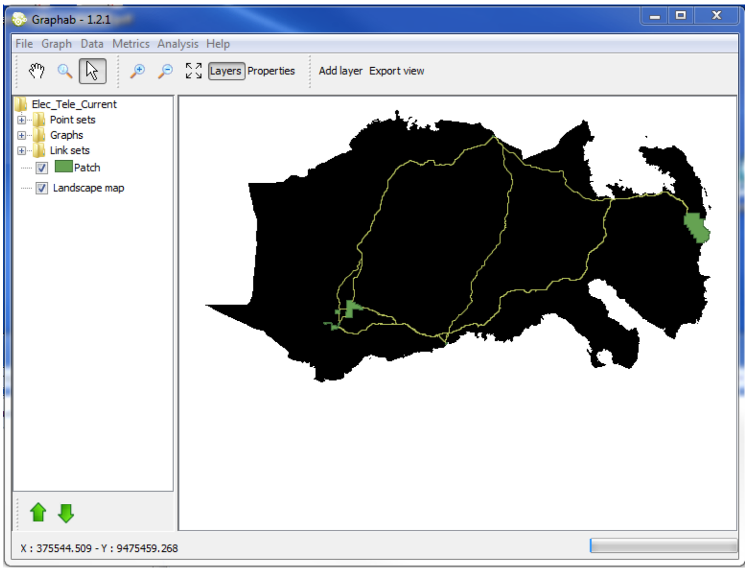
1. Identify node layer



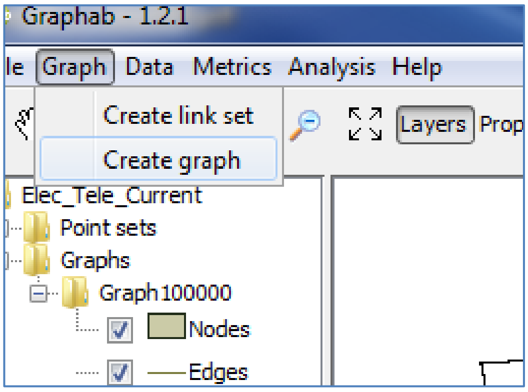
2. Identify cost surface

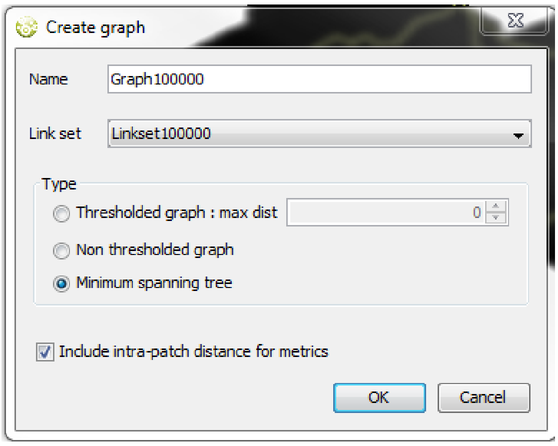


3. Output – least-cost path network

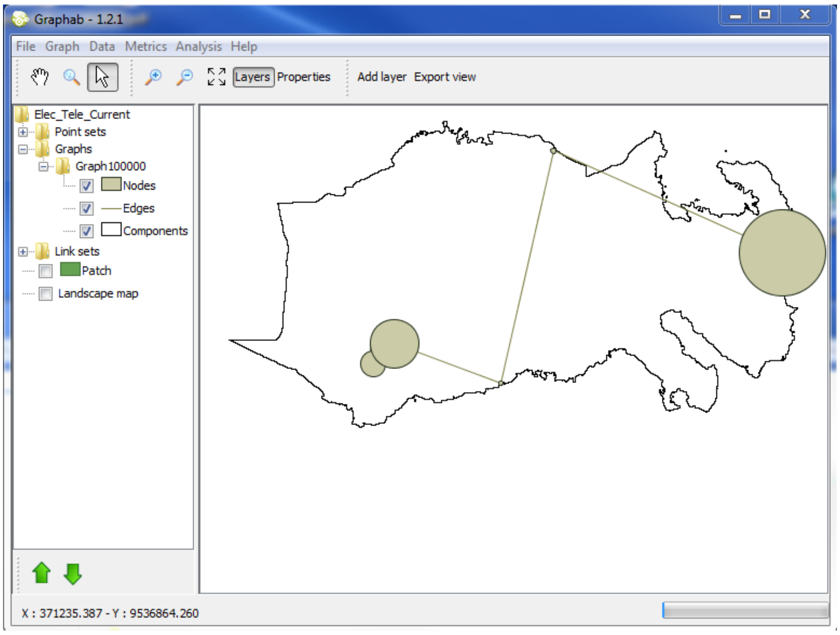


4. Identify minimum spanning tree





5.Output – minimum spanning tree



Python Script

```
=================================================================
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# Least-code path cost-surface processing tool
# Cost-surface processing.py
# Alex Lechner
# 28-04-2014
# Version 1.0
# ---------------------------------------------------------------------------
print "running"
import time
print "Starting at " + time.strftime('%d/%m/%y %H:%M:%S')
StartT=time.time()

# Import arcpy module
import arcpy,  re, os
import csv
import numpy as np
from arcpy.sa import *

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")

print " "
print "#########################################################"
print "      Least-code path cost-surface processing tool"
print "#########################################################"
print " "

####################################
# Local variables:
#RootDir = "D:\\_CSRM\\Projects\\AIIRA\\Workspace\\"
RootDir = "D:\\Alex\\_CSRM\\Projects\\AIIRA\\Workspace\\"
InputShpDir = RootDir + "InputData\\Factors\\"
InputDir = RootDir + "InputData\\"
outputDir = RootDir + "Output\\"
CostSurfaceFname = "costSurf"

ClipFile = InputDir + "Extent.shp"
CellSize = 100 #cellsize in m
CellSizeTopo ="100"

InputFilesAndWeightings = InputDir+"FilesAndWeightings.csv"

#Topography
```

```
InputContours= InputDir+ "Contours.shp ELEVASI Contour"
OutputRasterTopo = "topo"

rasterTemplate = outputDir+OutputRasterTopo

arcpy.env.overwriteOutput = True

#Rerun analaysis
rerunClipCheck = 1
retunTopoCheck = 1

##########################################

""" Setup """
os.chdir(RootDir) # Change current working directory for OS operations
arcpy.env.workspace = RootDir # Change current working directory for ArcGIS operations
print(os.getcwd()) #Current directory

#Check if temp directory exists - if not make it
if not os.path.exists(outputDir+"\\Temp"):
   os.makedirs(outputDir+"\\Temp")


##########################################
# RasterToTopo
# Local variables
# Process: Topo to Raster
if retunTopoCheck ==1:
   print ("====Running topo with cell size %s and input file -> %s" % (CellSize,
InputContours))
   OutputRasterTopo1 = outputDir+ "Temp\\" + OutputRasterTopo+"1"

   arcpy.gp.TopoToRaster_sa(InputContours, OutputRasterTopo1, CellSizeTopo, ClipFile,
"20", "", "", "ENFORCE", "CONTOUR", "20", "", "1", "0", "1")

   # Process: Slope
   inputTopo = OutputRasterTopo1
   outSlope = outputDir+ "Temp\\" + OutputRasterTopo+"2"
   arcpy.gp.Slope_sa(inputTopo, outSlope, "PERCENT_RISE", "1")

   # Process: Reclassify
   OutputRasterTopo2 = outputDir+OutputRasterTopo
   arcpy.gp.Reclassify_sa(outSlope, "Value", "0 3 1;3 25 2;25 90 5", OutputRasterTopo2,
"DATA")
   #arcpy.gp.Reclassify_sa(outSlope, "Value", "0 3 100;3 25 10", OutputRasterTopo2,
"DATA")
```

```
    print ("====Output topo-> %s" % (OutputRasterTopo1))


########################################
#Process and weight files

print ("====Process and weight files")

orignalCSV =np.genfromtxt(InputFilesAndWeightings,delimiter=',', dtype=None)

#listOfFiles = orignalCSV [1:3,0] # arrays are subsetted y,x
listOfFiles = orignalCSV [1:,0]


count=1
previouscurrentfilelocation =""

for currentfile in listOfFiles:
    currentfilelocation = InputShpDir+currentfile
    currentWeight = orignalCSV[count,1]

    getfilename = re.search('\\\\(.+?).shp', currentfile) #
    CurrentFilenameOnly = getfilename.group(1)

    print "currentfilelocation is: %s ,currentWeight is %s" % (currentfilelocation,
currentWeight)

    if currentfilelocation != previouscurrentfilelocation:
        ####################### only reanalyse the data if the next factor uses a different
file

        # Process: Clip
        ClipInput = currentfilelocation

        ClipOutput = outputDir+"Temp\\clip"+CurrentFilenameOnly+".shp"

        if rerunClipCheck == 1: #This
            arcpy.Clip_analysis(ClipInput, ClipFile, ClipOutput, "")

        # Process: Feature to Raster
        OutputRaster = outputDir+"Temp\\"+CurrentFilenameOnly[0:12]

        tempEnvironment0 = arcpy.env.snapRaster
        arcpy.env.snapRaster = rasterTemplate
        tempEnvironment1 = arcpy.env.extent
        arcpy.env.extent = rasterTemplate
```

```
    #arcpy.PolygonToRaster_conversion(ClipOutput, "FID", OutputRaster, "CELL_CENTER", "NONE", rasterTemplate)
    arcpy.PolygonToRaster_conversion(ClipOutput, "FID", OutputRaster, "MAXIMUM_COMBINED_AREA", "NONE", rasterTemplate)
    #arcpy.PolygonToRaster_conversion(ClipOutput, "FID", OutputRaster, "MAXIMUM_AREA", "NONE", rasterTemplate)
    arcpy.env.snapRaster = tempEnvironment0
    arcpy.env.extent = tempEnvironment1

    # Process: Change Raster value
    WeightedRasterFname = outputDir+"Temp\\"+CurrentFilenameOnly[0:12]+"1"

    WeightedRaster = Raster(OutputRaster)*0+float(currentWeight)

    #Convert Null values to 0
    WeightedRaster = Con(IsNull(WeightedRaster),0, WeightedRaster)

    WeightedRaster.save(WeightedRasterFname)

  previouscurrentfilelocation = currentfilelocation #Keep track of which files have been altered

  if count != 1:
    print "Modifying cost surface"
    CostSurface = Raster(outputDir+"Temp\\"+CostSurfaceFname+str(count-1))
    newCostSurface = Plus(CostSurface,WeightedRaster)
    newCostSurface.save(outputDir+"Temp\\"+CostSurfaceFname+str(count))
  else:
    print "Creating cost surface"
    WeightedRaster.save(outputDir+"Temp\\"+CostSurfaceFname+"1")

  count= count+1

  ###End loop

print "====Finished processing factors. final cost surface-> %s" % (outputDir+"Temp\\"+CostSurfaceFname+str(count))
#Process final cost surface and add topo surface

#open finalcostsurface and raster
FinalCostSurface = Raster(outputDir+"Temp\\"+CostSurfaceFname+str(count-1))
FinalCostSurface.save(outputDir+CostSurfaceFname+str(count))

TopoLayer = Raster(OutputRasterTopo2)

#Normalise - make all values positive - convert to cost weighting
```

```
FinalCostSurfaceMINresult =
arcpy.GetRasterProperties_management(outputDir+"Temp\\"+CostSurfaceFname+str(count-1),"MINIMUM")
FinalCostSurfaceMIN = FinalCostSurfaceMINresult.getOutput(0) #Get minimum values

FinalCostSurfaceMAXresult =
arcpy.GetRasterProperties_management(outputDir+"Temp\\"+CostSurfaceFname+str(count-1),"MAXIMUM")
FinalCostSurfaceMAX = FinalCostSurfaceMAXresult.getOutput(0) #Get maximum values

print "the maximum value is: %s ,the minimum values is %s" % (FinalCostSurfaceMAX , FinalCostSurfaceMIN)

MinPixel = abs(float(FinalCostSurfaceMIN))
MaxPixel= float(FinalCostSurfaceMAX)
maxminPixel=max([MinPixel,MaxPixel])
rangePixel = MaxPixel - MinPixel
CellSizeINT = int(CellSize)

#rescale cost surface
CostSurfaceRescaled = ((FinalCostSurface * -1)+ MaxPixel)*CellSize
CostSurfaceRescaled.save(outputDir+"Temp\\"+"CSRescale")

#Combine cost surface with topographic layer
TopographicInterval = rangePixel/5*CellSize
FinalCostSurface = CostSurfaceRescaled + TopoLayer * TopographicInterval

FinalCostSurface.save(outputDir+"Temp\\"+CostSurfaceFname+"INT")

#Mask Final feature
maskRasterIn = outputDir+"Temp\\"+CostSurfaceFname+"INT"
maskRasterOut = outputDir+"Temp\\"+CostSurfaceFname+"MSK"

arcpy.gp.ExtractByMask_sa(maskRasterIn, ClipFile, maskRasterOut)

#Raster mask  - remove areas outside boundary

""" ####### Export to Raster to Tiff"""
print "Export resistance file to Raster to Tiff"

# Local variables:
input_raster = maskRasterOut
output_raster = outputDir+CostSurfaceFname + ".tif"

# print output_raster

# Process: Copy Raster
```

```
# (in_raster, out_rasterdataset, config_keyword, background_value, nodata_value, onebit_to_eightbit, colormap_to_RGB, pixel_type
# "8_BIT_SIGNED" , "8_BIT_UNSIGNED" , "32_BIT_UNSIGNED", "32_BIT_FLOAT"
arcpy.CopyRaster_management(input_raster, output_raster, "", "", 0, "NONE", "NONE", "16_BIT_UNSIGNED", "NONE", "NONE") #Note the 0 value converts all 0 pixel values to NoData
#arcpy.CopyRaster_management(input_raster, output_raster, "", "", "", "NONE", "NONE", "16_BIT_UNSIGNED", "NONE", "NONE")
print ("====Output cost surface-> %s" % (output_raster))

print "Time elapsed:" +str(time.time()- StartT) + " seconds"
print "Finished at:"  +  time.strftime('%d/%m/%y %H:%M:%S')
```

```
# -*- coding: utf-8 -*-
# ---------------------------------------------------------------------------
# Least-code path node processing tool
# Node processing.py
# Alex Lechner
# 28-04-2014
# Version 1.0
# ---------------------------------------------------------------------------

print "running"

# Import arcpy module
import arcpy, time, re, os
import csv
import numpy as np
from arcpy.sa import *

# Check out any necessary licenses
arcpy.CheckOutExtension("spatial")

print "Starting at " + time.strftime('%d/%m/%y %H:%M:%S')
StartT=time.time()

####################################
# Local variables:
#RootDir = "D:\\_CSRM\\Projects\\AIIRA\\Workspace\\"
RootDir = "D:\\Alex\\_CSRM\\Projects\\AIIRA\\Workspace\\"
InputDir = RootDir + "InputData\\Nodes\\"    #Input directory for nodes
outputDir = RootDir + "Output\\"
#NodeFnameInput= "Elec_Tele_Future"
NodeFnameInput= "Elec_Tele_Current"
#NodeFnameInput= "Roads_Future"
#NodeFnameInput= "RoadsCurrent"
```

```
#NodeFnameInput= "access_road200"

NodeFname = NodeFnameInput[0:12]

ClipFile = InputDir + "Extent.shp"
#CellSize = 250 #cellsize in m

rasterTemplate  =  "D:\\Alex\\_CSRM\\Projects\\AIIRA\\Workspace\\Output\\costSurf.tif"
#setup raster template

arcpy.env.overwriteOutput = True

##########################################

""" Setup """
os.chdir(RootDir) # Change current working directory for OS operations
arcpy.env.workspace = RootDir # Change current working directory for ArcGIS operations
print(os.getcwd()) #Current directory

#Check if temp directory exists - if not make it
if not os.path.exists(outputDir+"\\Temp"):
   os.makedirs(outputDir+"\\Temp")


##########################################
   # node layer
# Process: Clip
ClipInput = InputDir + NodeFnameInput + ".shp"
ClipOutput = outputDir+"Temp\\c"+NodeFname+".shp"

arcpy.Clip_analysis(ClipInput, ClipFile, ClipOutput, "")

# Process: Feature to Raster
OutputRaster = outputDir+"Temp\\"+NodeFname

tempEnvironment0 = arcpy.env.snapRaster
arcpy.env.snapRaster = rasterTemplate
tempEnvironment1 = arcpy.env.extent
arcpy.env.extent = rasterTemplate
arcpy.PolygonToRaster_conversion(ClipOutput,    "FID",    OutputRaster,    "CELL_CENTER",
"NONE", rasterTemplate)
arcpy.env.snapRaster = tempEnvironment0
arcpy.env.extent = tempEnvironment1

# Process: Change Raster value
WeightedRasterFname = outputDir+"Temp\\"+NodeFname+"1"
```

```
WeightedRaster = Raster(OutputRaster)*0+1

#Convert Null values to 0
WeightedRaster = Con(IsNull(WeightedRaster),0, WeightedRaster)

WeightedRaster.save(WeightedRasterFname)

#Remove decimal places
FinalNode = Raster(outputDir+"Temp\\"+NodeFname+"1")
FinalNode1 = (FinalNode*100)+1

FinalNode1.save(outputDir+"Temp\\"+NodeFname+"I")

#Mask Final feature
maskRasterIn = outputDir+"Temp\\"+NodeFname+"I"
maskRasterOut = outputDir+"Temp\\"+NodeFname+"M"

arcpy.gp.ExtractByMask_sa(maskRasterIn, ClipFile, maskRasterOut)

#Raster mask  - remove areas outside boundary

""" ####### Export to Raster to Tiff"""
print "Export Node file to Raster to Tiff where 1 = background, 101 = nodes and NoData = 3"

# Local variables:
input_raster = maskRasterOut
output_raster = outputDir+NodeFname + ".tif"

# print output_raster

# Process: Copy Raster
# (in_raster, out_rasterdataset, config_keyword, background_value, nodata_value, onebit_to_eightbit, colormap_to_RGB, pixel_type
# "8_BIT_SIGNED" , "8_BIT_UNSIGNED" , "32_BIT_UNSIGNED", "32_BIT_FLOAT"
arcpy.CopyRaster_management(input_raster, output_raster, "", "", 0, "NONE", "NONE", "16_BIT_UNSIGNED", "NONE", "NONE") #Note the 0 value converts all 0 pixel values to NoData
#arcpy.CopyRaster_management(input_raster, output_raster, "", "", "", "NONE", "NONE", "16_BIT_UNSIGNED", "NONE", "NONE")

print "Time elapsed:" +str(time.time()- StartT) + " seconds"
print "Finished at:"  +  time.strftime('%d/%m/%y %H:%M:%S')
```

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