Potential Surface Analysis in Urban Sustainability Planning: A Case Study in Mae Ka, Phayao, Thailand

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Abstract
This study aimed to achieve three objectives: firstly, to analyze the urban growth around the Mae Ka community by examining the land use changes that occurred in 2001, 2011, and 2021; secondly, to identify the factors that affect the potential areas for development; and thirdly, to propose sustainable development guidelines for both the Mae Ka community and the surrounding areas. To accomplish this, the study employed Potential Surface Analysis (PSA) as a method for evaluating suitability and development potential. The study utilized Geographic Information System (GIS) to process three major factors: physical, infrastructural, and risk area factors. The overlay mapping technique was crucial in analyzing and classifying areas based on their potential for supporting the development plan for the Mae Ka community. The areas were divided into three categories: high potential areas, moderate potential areas, and low potential areas. The results of the analysis land use changes revealed that in 2001, 2011 and 2021, forest areas decreased by 11.74%, with a conversion to agricultural areas, build-up areas, and miscellaneous areas, resulting in a decrease from 149.92 square kilometers to 132.32 square kilometers. Furthermore, the results of the potential surface analysis using physical, infrastructural, and risk area factors demonstrated that the high potential areas constituted 23.74 square kilometers or 8.58%, the moderate potential areas comprised 64.39 square kilometers or 23.28%, the low potential areas covered 55.75 square kilometers or 20.16%, and the excluded areas, such as forest areas, reserved or preserved areas, and natural resource areas, accounted for 132.70 square kilometers or 47.98% of the total area. Based on the level of potential areas, recommendations for stable and sustainable land use plans, transportation plans, and infrastructure plans can be developed for Mae Ka in the near future.

Keywords: Potential Surface Analysis, Thailand, Urban Sustainability Planning

1. Introduction

Since the implementation of the Fifth National Economic and Social Development Plan (1982-1986), the three upper northern provinces, namely Phayao, Mae Hong Son, and Nan, have been identified as target areas for development. This was done to alleviate the pressure on cultivated land and to create a special area to improve land use efficiency, water resources, and forests while increasing the average income of individuals in the upper northern region, which is currently lower than the national average. Additionally, the northern plan of the year 2057 formulated guidelines for the development of urban systems, emphasizing the various roles played by different urban communities in the region. The central cities in the north, such as Chiang Rai, Chiang Mai, Phitsanulok, and Nakhonsawan, are considered growth poles. Meanwhile, provincial-level prosperity centers include Mae Hong Son, Lamphun, Lampang, Phayao, Uttaradit, Tak, Sukhothai, Kamphaengphet, and Phetchabun [1]. The development policy mentioned above has had a significant impact on Phayao, which is part of the community system in the upper northern region. This is evident through the expansion of the urban area, establishment of the University of Phayao, and increase in population, employment, housing, commerce, and public utilities. The urban area has rapidly expanded into rural areas, particularly the Mae Ka subdistrict in Mueang Phayao, Phayao Province, which surrounds the University of Phayao.

As noted, the expansion of Phayao University has become a phenomenon where urbanization originates and spreads to the surrounding areas, affecting the community both physically and economically, as well as socially [2]. The emergence of housing estates and commercial buildings in previously vacant areas and on the outskirts of the city illustrates the economic growth, infrastructure construction, and establishment of public utilities and facilities [3]. However, these developments often aim to solve immediate problems and may create long-term issues such as urbanization, building expansion, encroachment on green spaces and agricultural areas, sewage water problems, garbage problems, air pollution, and disappearance of rural areas [4] and [5]. Without proper direction and control over urban growth and inefficient city management, these issues will persist.

Although the conceptual framework of urban planning is prominent in controlling urban development for orderly growth, most of the designated goals still focus on promoting economic growth, expanding public and private sector investments, and becoming the economic and service center of the region. Urban planning does not necessarily require limiting urban growth and controlling urban expansion, which can lead to effective management of public utilities and services, ultimately improving the quality of life in the city [6]. Sustainable urban development, on the other hand, refers to urban planning and guiding principles that aim to improve and build cities without overusing resources. The focus is on generating employment and business opportunities, ensuring the provision of safe and affordable housing, and fostering the development of resilient societies and economies. This requires investments in public transportation systems and the creation of public green spaces and promoting sustainable land-use planning and management in participatory and inclusive ways [7] and [8]. Therefore, the objectives of this study are threefold: first, to examine the land use changes in the Mae Ka community and surrounding areas; second, to identify the factors that affect the potential areas for development; and finally, to propose sustainable development guidelines based on land use plans, transportation plans, and public utility plans to improve the sustainable quality of life for the people in the future.

2. Study Area

The study area is Mae Ka Subdistrict where located within Mueang Phayao, Phayao Province. It serves as a gateway subdistrict of Phayao Province since it borders Ban Rong Subdistrict, Ngao, Lampang Province. Mae Ka Subdistrict covers an area of approximately 131.69 square kilometers, or 82,310 rai. The geography of the area is generally hilly and mountainous in the southern and western areas, covered with forested hills. These regions are the source of several streams that flow through various villages towards the north, eventually draining into Kwan Phayao. The northern and eastern areas consist of lowlands and foothills (Figure 1).

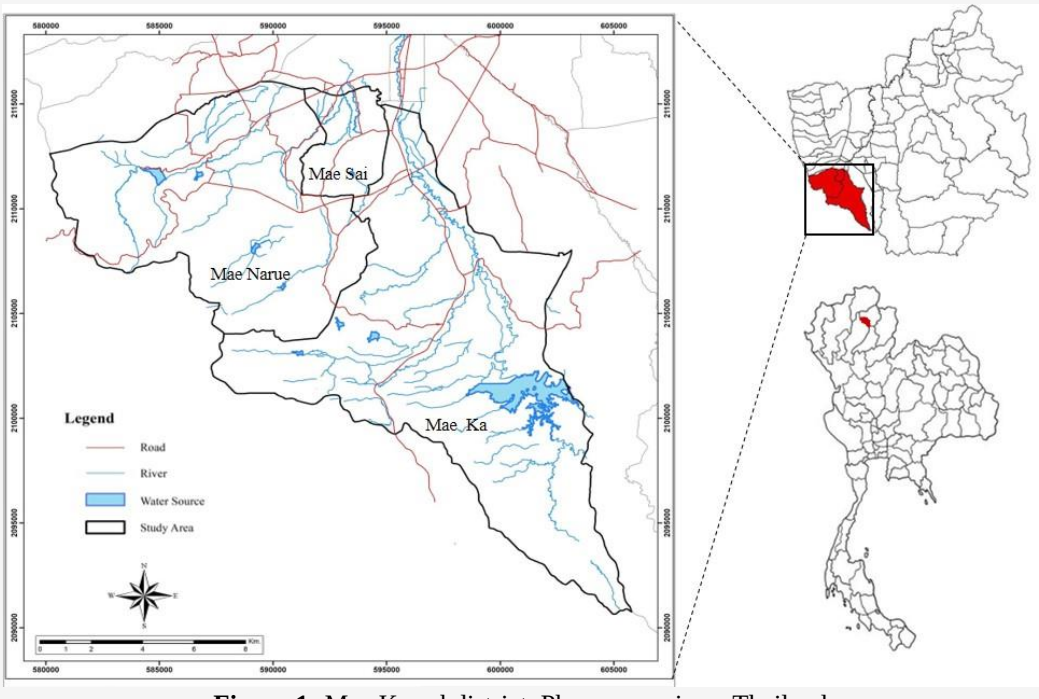

Figure 1: Mae Ka subdistrict, Phayao province, Thailand

3. Research Methodology

The research methodology was divided into three main parts; each of which was applied to achieve the research objectives as shown in Figure 2. The parts are described as follow:

3.1 Analysis of Land Use Changes

In methodology, the study used a GIS-based spatiotemporal analysis in ArcGIS program that studied land use changes based on land use dataset during 2001, 2011 and 2021 from Land Development Department (LDD), Thailand. The method included two main steps as:

3.1.1 Data collection

The primary data, which contained information on the context and current conditions of the study area, were collected through field surveys and observations specifically for land use analysis and verification. Secondary data, including descriptive information and relevant publications, were compiled from relevant agencies and transformed into attributed data in Geographic Information System (GIS) [9]. For data collection and preparation based on land use from 2001, 2011, and 2021 provided by the Land Development Department (LDD) includes GIS layers of Phayao and Mae Ka land use [10] and the classification based LDD land use classification system. The land use data layer consists of land use types categorized into Level 1, which consists of forest, agriculture, water bodies, built-up areas and miscellaneous area, classified according to the standard land use classification system. This classification is based on the analysis and interpretation of satellite imagery or aerial photographs, combined with field survey data. The data is input through a process of digitization to convert it into numerical data. The land use data is stored in the form of a vector map as digital data. It was meticulously checked, examined, and updated using high-resolution data from the corresponding periods. Spatial enhancement technique was applied to improve the image quality.

3.1.2 Analysis of spatiotemporal data

Spatiotemporal analysis typically facilitates both spatial and time-series investigations, enabling the monitoring, detection, and evaluation of persistent patterns over time at specific locations. In this study, spatiotemporal analysis using GIS was employed as a valuable tool for modeling and detecting environmental changes. In the processing stage, the spatiotemporal data included land use change based 1st level of LDD land use classification system such as forest, agriculture, water bodies, built-up areas and miscellaneous area. Classification of land use is performed using image classification techniques, categorizing the data into predefined land use types.

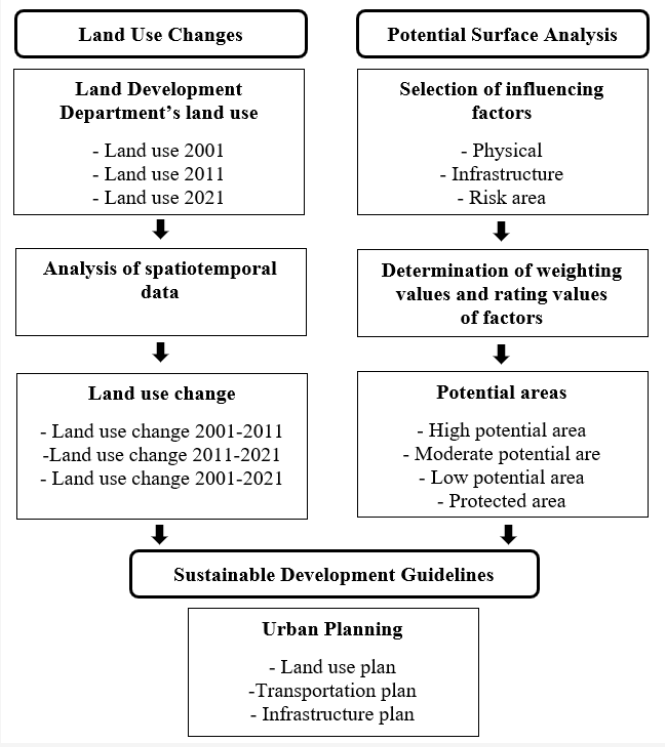

Figure 2: Flowchart of methodology

Change detection is then carried out by comparing land use maps from different time periods, overlaying them to identify and quantify changes. To enhance accuracy, image interpretation is often supplemented with field surveys. This involves physically visiting the land to verify the classifications made from the imagery. For example, a field survey might confirm whether a patch of green seen in an image is indeed agricultural land or just wild vegetation. This analysis reveals patterns and trends, helping to understand the driving factors behind the changes, such as urbanization or agricultural expansion. Visualization tools, including table, bar chart and map, are used to present the findings, which are compiled into a comprehensive report. The final step involves reviewing and validating the results with stakeholders or experts and formulating recommendations for future land use planning and management, emphasizing sustainable development goals and the needs of local communities.

3.2 Potential Surface Analysis

The research utilized the Potential Surface Analysis (PSA) technique to analyze potential suitable areas for urban development. The PSA technique is useful for urban planning as it can provide a scientific and objective basis for decision-making regarding land use planning and management. It can help to identify areas that are suitable for different types of development and prioritize areas for development based on their potential and compatibility with existing infrastructure and services. By applying this technique, urban planners and policymakers can make informed decisions that advance sustainable development initiatives and improve the quality of life for the people in the study area. This technique provides an alternative approach for evaluating and analyzing potential areas for residential, industrial, commercial, and recreational land uses [11]. PSA originated from the overlay mapping technique and integrates both spatial and attribute data within a GIS [12]. The main function of PSA is to weigh factors, and this technique provides potential areas ranging from low to high potential. This technique has been widely used in various fields of study in the past decade, including geography, environmental science, landscape architecture, and urban planning. The data analysis process was as follows:

3.2.1 Selection of influencing factors

The factors that qualify are mostly determined by their relation to urban development [13]. Factors affecting development for Potential Surface Analysis (PSA) were gathered from relevant literature and consultations with experts. These factors were categorized into three groups: physical, infrastructure, and risk areas. The PSA method was then applied in GIS to study urban development processes based on these factors [14]. The first category includes factors that affect physical urban development, this includes the creation and improvement of urban functionality such as slopes, water sources, roads, railway, and railway station. In addition, physical factors encompass a broader range of elements, including natural features and other man-made structures that may not be essential for societal functioning. The second category comprises infrastructure factors, focusing on the necessity for societal functioning and growth. It includes facilities and systems that are crucial for economic activities, public services, and overall development. In this study, the infrastructure includes urban areas, schools, hospitals, health stations, police stations, fire stations, and markets. Finally, the risk area category includes flood risk area, drought risk area, and landslide risk area, as shown in Figure 3. Each factor should be transformed into a shapefile or represented as a detailed map with appropriate attributes and consistent scales, all produced at the same mapping scale. It is crucial to not only verify but also correct any discrepancies in the shapefiles before their application.

3.2.2 Determination of weighting values and rating values of factors

This step is important in the potential surface analysis for sustainable development. The weighting value represents the importance score of each factor and is determined through a process that also establishes the rating value. In terms of determination of weighting values of factors, this involves assigning values to groups of factors that influence or relate to the potential for urban expansion. Factors with the greatest influence are assigned a group weight of 3 points, which signifies their importance in facilitating urban expansion. Factors with a moderate influence are assigned a group weight of 2 points, indicating their role in supporting the city's completeness in terms of functions and services to the population. Factors with the least influence are assigned a group weight of 1 point, which denotes their unsuitability for urban development. As for determination of rating, this involves assigning scores to factors based on their level of significance. For this study, integer values ranging from 1 to 3 will be used, where a score of 3 indicates the factor is most suitable, a score of 2 shows moderate suitability, and a score of 1 mentions the factor is least suitable as shown in Table 1.

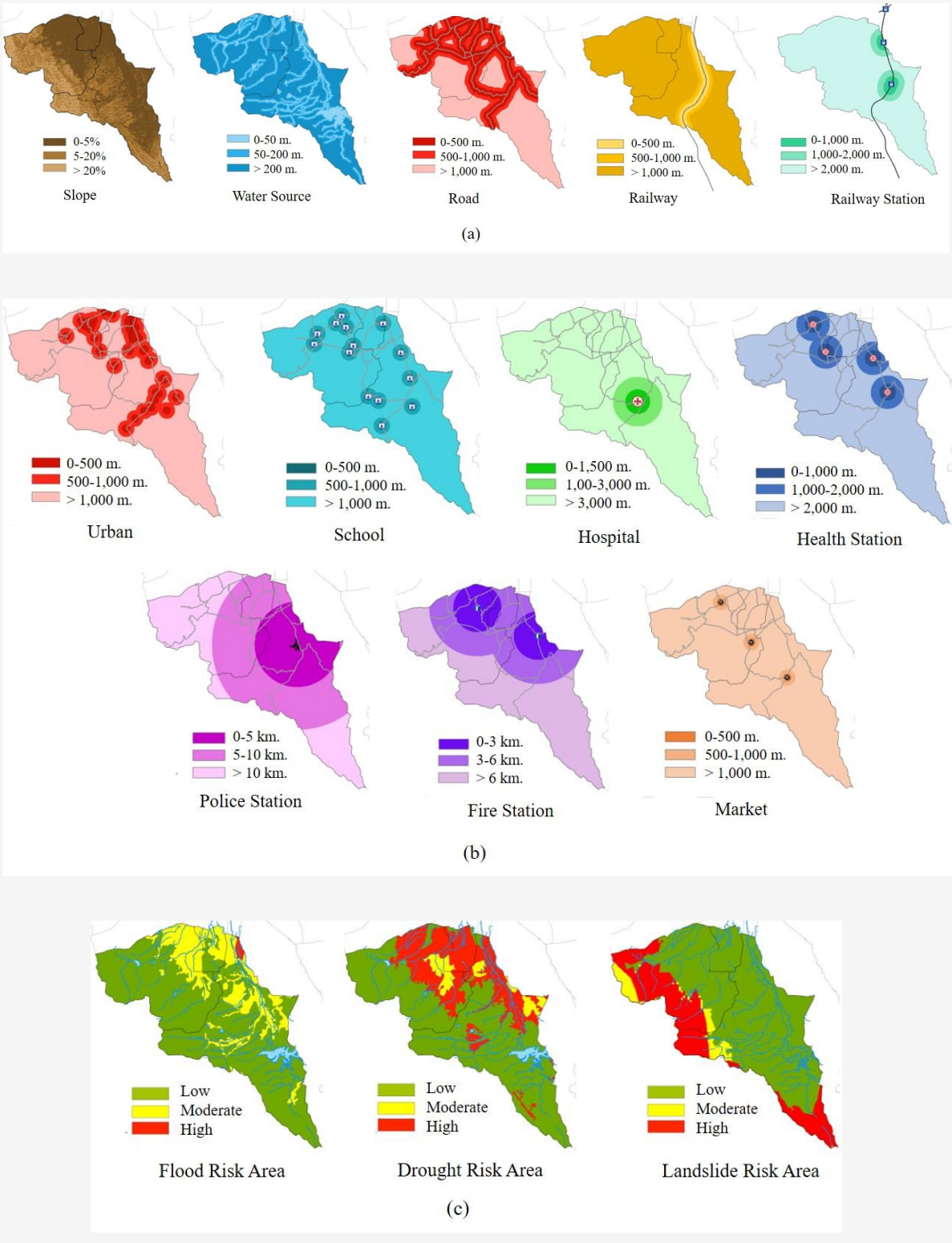

Figure 3: Influencing factors in potential surface analysis
(a) physical (b) infrastructure and (c) risk area

Table 1: Weighting value and rating value of factors

Factor	Scoring criteria	Weighting	Rating		
			3	2	1
Physical					
Slope	Slope percentage (%)		0-5	5-20	> 20
Water Source	Distance from water source (m.)		> 200	50-200	0-50
Road	Distance from road (m.)	3	0-500	500-1,000	> 1,000
Railway	Distance from railway (m.)		> 1,000	500-1,000	0-500
Railway Station	Distance from railway station (m.)		0-1,000	1000-2000	> 2,000
Infrastructure					
Urban areas	Distance from urban areas (m.)		0-500	500-1,000	> 1,000
School	Distance from school (m.)		0-500	500-1,000	> 1,000
Hospital	Distance from hospital (m.)		0-1,500	1,500-3,000	> 3,000
Health Station	Distance from health station (m.)	2	0-1,000	1,000-2,000	> 2,000
Police Station	Distance from police station (km.)		0-5	5-10	> 10
Fire Station	Distance from fire station (km.)		0-3	3-6	> 6
Market	Distance from market (m.)		0-500	500-1,000	> 1,000
Risk Area					
Flood Risk Area	Level of flood risk area		Low	Moderate	High
Drought Risk Area	Level of drought risk area	1	Low	Moderate	High
Landslide Risk Area	Level of landslide risk area		Low	Moderate	High

To determine both the weighting value and rating value, urban planners use questionnaires and rely on the input of experts in the field. These experts are selected based on their professional background and expertise, and their responses are used to establish the relative ratio of importance for each factor in percentage terms.

3.2.3 Data manipulation

Before conducting the Potential Surface Analysis (PSA) in Arc GIS, the weighting score and range of rating scores for each factor were determined and calculated in an excel spreadsheet. The weighting score represents the importance of each factor in the analysis, while the rating score determines the level of suitability of each factor for urban development. Then the suitability (S) was calculated using the following:

$$S = \sum_{i=1}^{n} W_i F_i$$

Equation 1

Where:

S = Suitability or potential area
W = Weighting value of each factor
F = Influencing factors
i = Corresponding weights
n = Total numbers of the factors

3.2.4 Displaying area from PSA

The data presentation displays the results of the range calculated for dividing the suitable rank areas. The outcome shows the areas suitable for urban development according to the criteria specified in the appropriate format digital maps [15]. The area is divided into four categories: 1) high potential areas are areas with the highest potential for development according to their physical characteristics, such as areas that are easily accessible, have adequate public utilities and infrastructure, do not have a negative impact on the environment, and are not located in areas prone to natural disasters, 2) moderate potential areas are areas that are suitable for development but may have some physical limitations, but not significant limitations, or may have to be considered on physical limitations in development, 3) areas with low potential for development are areas where there are significant physical limitations to development, such as being inaccessible, having a negative impact on the environment, and being located in areas prone to natural disasters, 4) reserved and conservation areas are forest or reserve areas in high mountain areas, according to the announcement regarding conservation forest areas, national forest reserves, and laws related to the conservation and protection of wildlife.

3.3 Propose Development Planning Guidelines

The area analyzed by the PSA method can provide suggestions for urban development guidelines that can lead to recommendations for area development planning to support sustainable future growth. This includes determining the land use plan, transportation plan, and infrastructure plan.

These guidelines will be valuable for planners to utilize the research results effectively.

4. Results

In this section relates to the study results which can be divided into 3 parts as follows:

4.1 Change of Land Use

The detection of land use and land cover change utilized a post-classification comparison change detection method, which is the most used quantitative method for detecting changes [16]. The land use maps of the study area for the years 2001, 2011, and 2021 were produced from land use data in the form of a shape file of LDD and are illustrated in Table 2 and Figure 4 depicting the land use for the two study periods of 2001-2011 and 2011-2021, respectively. Quantitative data on the overall land use in each category for the two study periods were compiled. During the study period from 2001 to 2011, the forest area decreased by 12.36 square kilometers. On the other hand, agricultural areas, water resources, built-up area, and miscellaneous area increased in area by 9.65, 0.66, 1.21, and 0.84 square kilometers, respectively. The primary cause of forest area loss was attributed to the establishment of the University of Phayao and encroachment by agricultural, built-up, and miscellaneous areas (Figure 5). During the second study period, from 2011 to 2021, the forest area decreased by 5.24 square kilometers and the agricultural area also decreased by 0.84 square kilometers. Most of the agricultural land was used for farming, cultivating vegetables, and horticulture. While the water resources, built-up area, and miscellaneous area increased by 2.27, 3.66, and 0.15 square kilometers, respectively. The analysis revealed that approximately 40% of the increase in the total area of water resources was due to the urban expansion and community needs.

Additionally, since the establishment of the University of Phayao in 1999, the built-up area has continuously expanded, with rapid growth in commercial buildings, residences, dormitories, and shops, particularly in the community in front of University of Phayao. The land use changes indicate that the community or building expansion has increased on both sides of Phaholyothin Road or Highway No.1, extending from the center area to nearby areas, reflecting the crucial role of the University of Phayao as an educational center.

Table 2: Land use change during 2001-2021

Land Use	Area			Land Use Change					
	2001	2011	2021	2001-2011		2011-2021		2001-2021	
	Area (km^2)	Area (km^2)	Area (km^2)	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Forest Area	149.92	137.56	132.32	-12.36	-8.24	-5.24	-3.81	-17.6	-11.74
Agricultural Area	96.6	106.25	105.41	+9.65	+9.99	-0.84	-0.79	+8.81	+9.12
Water Resource	4.82	5.48	7.75	+0.66	+13.69	+2.27	+41.42	+2.93	+60.79
Built-up Area	19.76	20.97	24.63	+1.21	+6.12	+3.66	+17.45	+4.87	+24.65
Miscellaneous Area	5.48	6.32	6.47	+0.84	+15.33	+0.15	+2.37	+0.99	+18.07

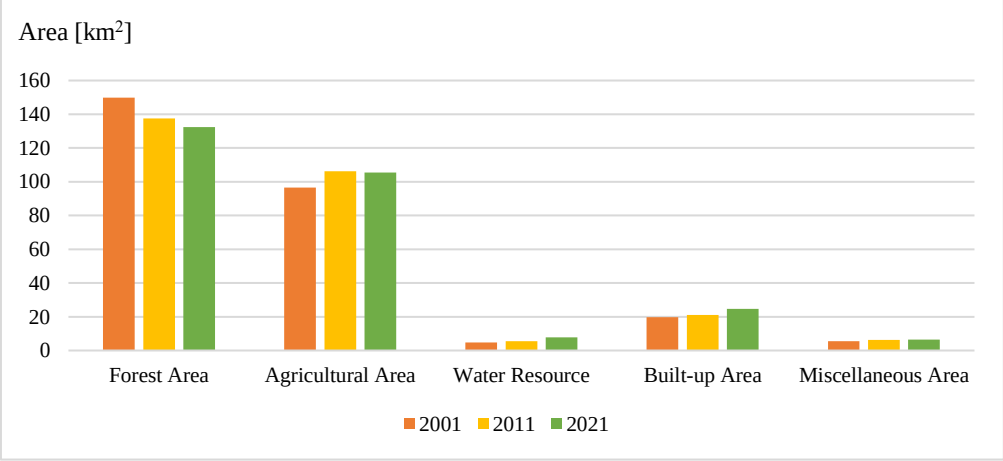

Figure 4: Land use change in 2001, 2011 and 2021

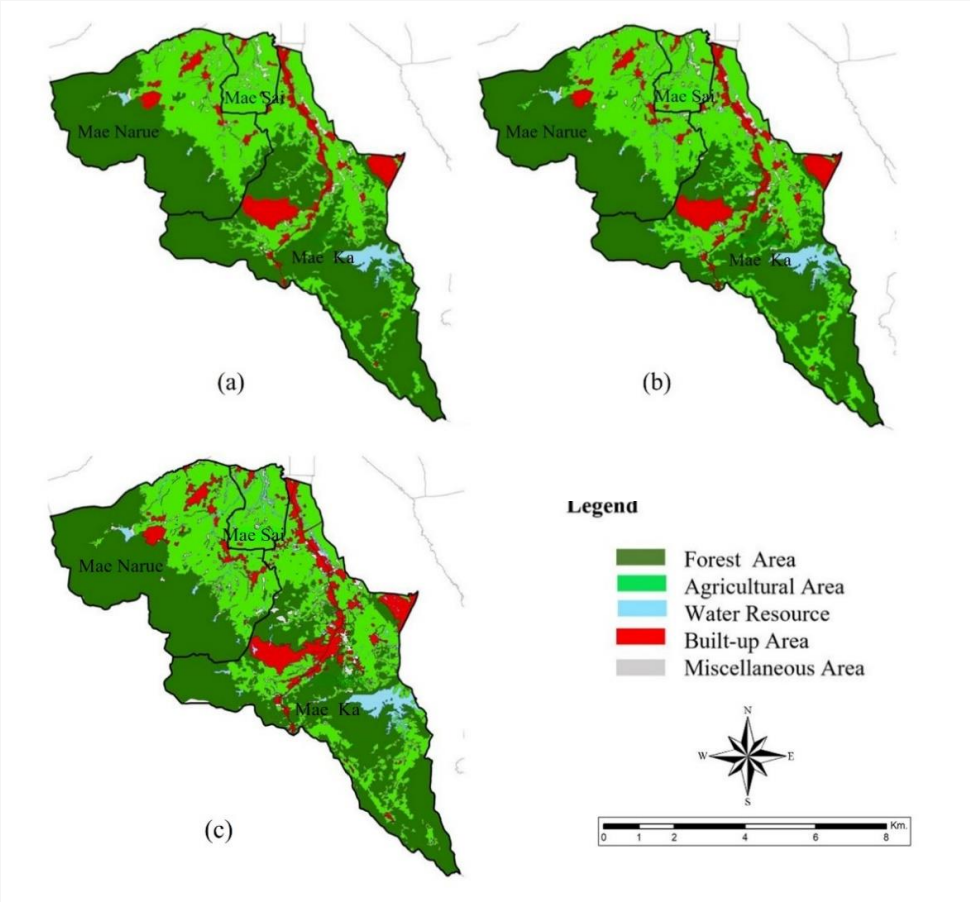

Figure 5: Land use classification
(a) 2001, (b) 2011 and (c) 2021

4.2 The Potential Surface Analysis for Urban Development

The results of this study identify and rank suitable areas for urban development using the Potential Surface Analysis (PSA) method by weighing and rating physical, infrastructure, and risk area factors. The analysis shows that the potential areas are divided into four levels as follows: high potential areas or areas for promoting urban growth covering 23.74 square kilometers or 8.52 percent, moderate potential areas or areas reserved for future urban growth covering 64.39 square kilometers or 23.28 percent, low potential areas or areas conserved for agriculture and food production covering 55.75 square kilometers or 20.16 percent, and protected areas or areas reserved for forest and watershed covering 132.70 square kilometers or 47.98 percent, respectively. The details are described, and the figure is shown in Figure 6.

4.2.1 The high potential area or area for promoting urban growth

The first potential area identified as most suitable for development is typically the community area, which should be fully developed as an economic or community center [17]. This area is compact and diverse in land use, allowing for efficient and cost-effective land utilization. The integration of commercial, residential, recreational, and educational institutions should be easily accessible and linked by traffic [18]. The presence of economic activities, recreation, and housing contributes to the vitality and distinctive identity of the community. In the current study area, the zone for promoting urban growth must be an area with urban characteristics, including lots of built-up areas and various economic activities, without any forested or conserved areas.

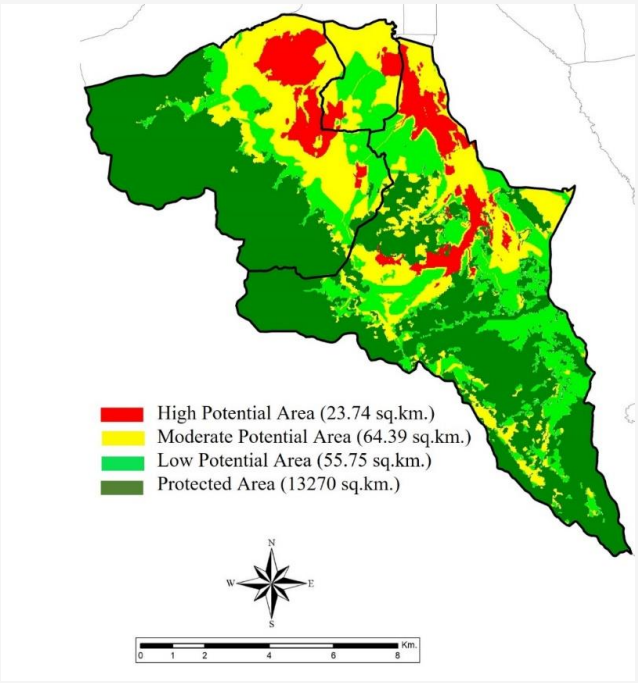

Figure 6: Classification of the potential area

The high potential area for promoting urban growth is the community settlements on both sides of Phaholyothin Road (Highway No.1), especially in front of the University of Phayao, Mae Ka Sub-district, and Highway No. 120. Some communities located on both sides of the Phayao-Wang Nuea Road and Ban Mae Na Rua Tai Mae Na Ruea Sub-district have begun to develop into urban centers. Various land use types and economic activities are being carried out and are likely to continue developing in the future.

4.2.2 The moderate potential area or area reserved for future urban growth

The area with moderate potential for development is typically a rural area located close to the city, yet still maintaining its natural green space. However, there is a tendency for this area to develop in the future, making it suitable for further development. This area will be reserved for development to support future expansion [19]. Additionally, this area is designated as a green area and can be used as an open space and recreation area for the community. The area reserved for future urban growth should be connected to the community area or existing urban area that has begun to be settled but is not yet very dense. It still has vacant green areas and mixed agricultural land. Therefore, the area reserved to support urban expansion is usually located outside the original community area and on the main road.

4.2.3 The area conserved for agriculture and food producing

The areas with low potential for development are rural, agricultural, and agricultural land reform areas. These areas are best suited for agriculture and should not be developed for economic purposes unless they are developed for tourism or as agricultural learning centers [20]. These areas are vital for the city's agriculture and food supply and deserve conservation to remain sustainable for the community. Due to scattered settlements, communities, and buildings encroaching on agricultural and natural areas, the city is losing its green space, natural balance, and sources of food production and livelihood [21]. These areas comprise wetlands, lowland areas, waterfront areas, and current agricultural areas. They will serve as green areas, recreation areas, and community food sources for the city's food supply. Most of them cover the entire area of Mae Ka Sub-district, Mae Na Ruea Subdistrict, and Mae Sai Subdistrict, which are home to rice fields, pumpkin plantations, garlic plantations, corn plantations, and more. These areas not only help to promote the economy of Muang Phayao District but also provide farmers with a reliable source of income. If allowed to develop, these areas will disappear, as has happened in the past.

4.2.4 The protected area or area reserved for forest and watershed

This area is covered by high mountains and the land is used to preserve and protect forests, wildlife, watersheds, streams, and other natural resources, as mandated by the National Forest Reserve and Wildlife Protection Law. Its condition necessitates preservation as a biodiversity area to maintain ecosystem balance, and use of the land for other purposes is prohibited [22]. Most of the land is situated around national forests, including Mae Tam Forest and Mae Na Ruea Forest in Mae Na Ruea Sub-district, as well as Mae Tam Forest in Mae Ka Sub-district. Preserving these protected areas is crucial for the long-term health and sustainability of the ecosystem. It provides habitat for a diverse range of wildlife and helps maintain the balance of the local water cycle. Additionally, protected areas can serve as important sites for scientific research and education, as well as opportunities for eco-tourism [23]. It's important to maintain strict regulations and enforcement to ensure that these areas are not encroached upon or used for purposes other than conservation.

4.3 Sustainable Development Guidelines for Urban Planning

In this section, the results of PSA illustrated the present physical condition and appropriateness of potential development areas. Therefore, sustainable development suggestion included land use plan, transportation plan and infrastructure plan as the following:

4.3.1 Land use plan

A land use plan is a significant process that aims to manage and regulate land use activities to ensure sound urban and balanced regional development [24]. The land use planning dominates the development and utilization of land in accordance with the public interest, aiming to balance the demands of development with the need for conservation to promote sustainable development [25]. There is an increasing awareness in Thailand of the need to steer urban development to avoid an unsustainable structure. The land use plan in this research seeks to consolidate essential urban functions within the city center to support daily life while maintaining a sustainable urban structure with appropriate population density. It also aims to ensure that the city remains both resident-friendly and environmentally sustainable [26].

Therefore, the Mae Ka subdistrict in the center of the community should be defined as a mixed-use area, combining commercial, employment sources, and medium to high-density residential. This area is designated as a center or cluster to provide commercial, trade, and service functions to the community, enhancing convenience for residents. It is intended to support investment and development in activity centers and employment hubs both now and in the future, as well as to increase the value of investment in public utilities and infrastructure. This will enable some of the people to reduce their travel distances. The surrounding areas of the community center should be designated as low-density residential and agricultural areas. The agricultural area plays an important role as a source of food production. In terms of industrial areas and warehouses (such as the Kaset Suk Intersection), they should be isolated from the community to prevent interference with the quality of life of the residents. As for recreational areas, Thai art and cultural conservation areas, protected areas including forests, and land reform areas should be promoted and controlled for national reserved forests, wildlife watersheds, and other natural resources [27]. This is shown in Figure 7.

4.3.2 Transportation plan

The transportation plan is essentially the confluence of many different disciplines that come together in the initial stages of the planning process [28]. It involves evaluating the existent state of transportation in the region and developing plans to address future transportation needs, and incorporating budgets, goals, policies, and legislative activities. Moreover, it plays a critical role in shaping the growth of a community or city by evaluating various transportation elements, including streets, highways, cargo shipping, public transit, and bike lanes. This process has the potential to influence multiple aspects, such as business activities, recreational opportunities, and overall quality of life. High-quality public transport services that consist of a dense network of routes and short waiting times at stops can only be operated economically efficiently when the ratio of customer trip kilometers to bus kilometers is high [29]. In other words, high occupancy rates of buses must be guaranteed.

Long-term sustainable transportation strategies should involve modifying the urban structure itself. For instance, transportation demands concentrated in city center areas can be redistributed to sub-centers and peripheral urban areas, thereby alleviating congestion and fostering the development of a more balanced and equitable urban environment. Moreover, sustainable transportation should serve societal needs by ensuring safety, protecting human health, and minimizing disruptions to communities.

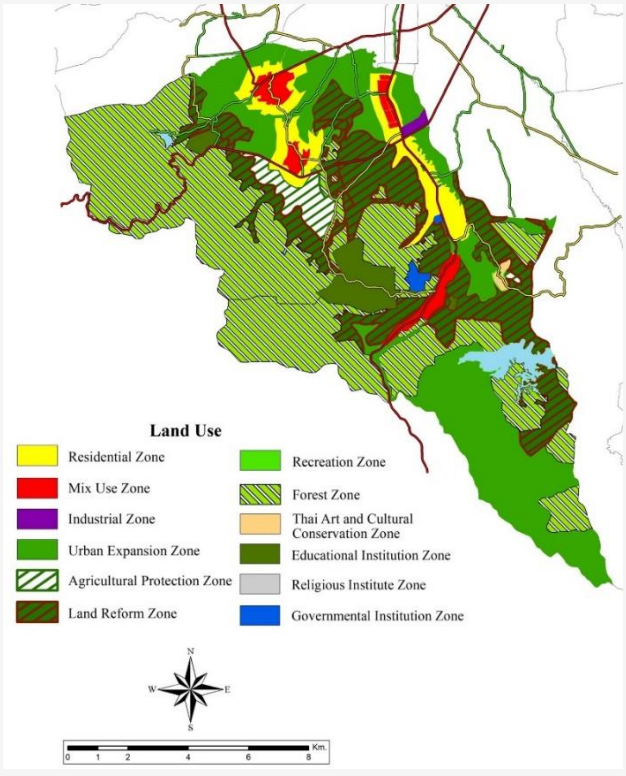

Figure 7: Land use plan

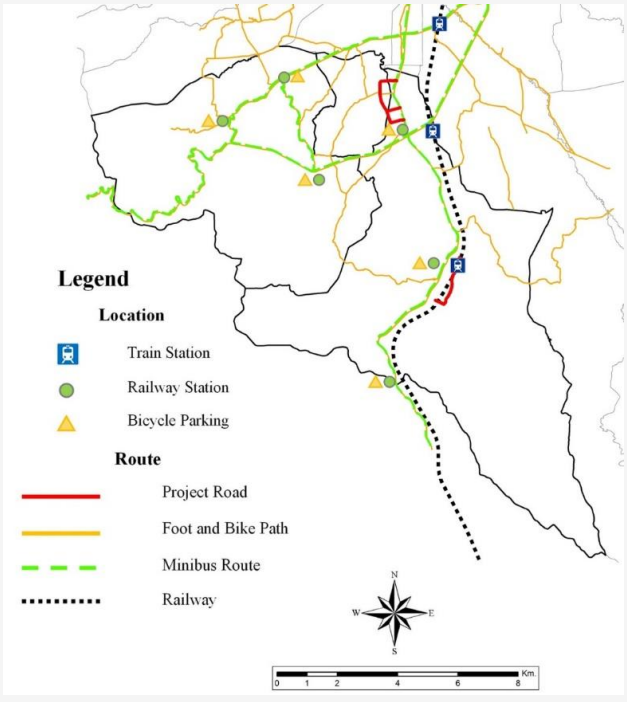

Figure 8: Transportation plan

Additionally, access and equity are crucial principles, as transportation systems should enhance access to goods and services for as many individuals as possible [30]. In this regard, the transportation plan also suggests that a new road network connection has been established to achieve traffic connection in the community area by connecting a secondary road along Phaholyothin Road to Samakkee Road and the area in front of the University of Phayao, as shown in Figure 8.

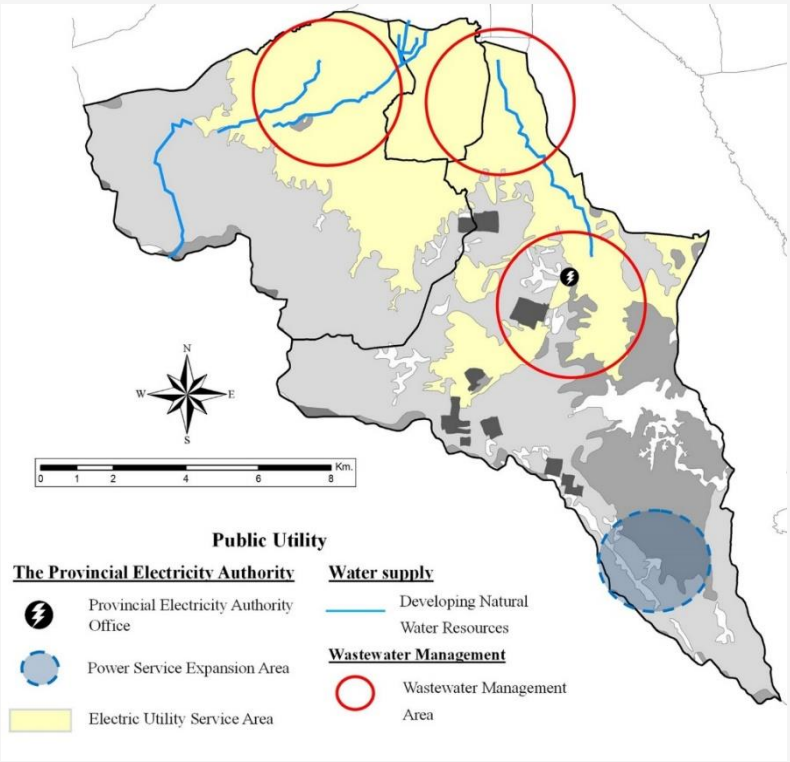

Figure 9: Infrastructure plan

4.3.3 Infrastructure plan

Infrastructure plays a pivotal role in the development of sustainable cities, while effective planning is essential for establishing sustainable infrastructure [31]. Infrastructure planning addresses the fundamental facilities and systems that support a city and its residents, aligning these resources with the goals outlined in the strategic plan. This aspect of urban planning encompasses both civic infrastructures, including sewage systems, water distribution, power supply, and telecommunication systems, as well as public amenities, such as healthcare centers, educational institutions and recreational areas. Investment in infrastructure represents an investment in places, people, and communities, as it subtly underpins the daily functioning of life [32]. There is growing recognition of the importance of functional and streamlined infrastructure for both regional and national economic accomplishment. Research indicates that there are measurable connections between investment in infrastructure, competitiveness, and productivity [33]. Thus, the infrastructure plan in the study area should focus on expanding electricity services and ensuring adequate water supply to meet the needs of the communities, as shown in Figure 9. Failing to invest in infrastructure can have significant societal and economic consequences, as infrastructure plays an important role in tackling environmental challenges and shifting towards a zero-carbon future. Infrastructure development is influenced by various factors, including land use, geography, architecture, cost, and risk management. It is important to recognize that rural and urban planning necessitate distinct approaches. Successful infrastructure development requires strategic and comprehensive partnerships among multiple service delivery entities [34].

5. Discussion

Based on this research, Potential Surface Analysis (PSA) was applied to make the urban plan. This was done by measuring the overlay between the factors that influence suitable areas, including physical, infrastructure, and risk areas. The PSA method was developed from Sieve Analysis and other mathematical methods. It is a systematic land evaluation technique that is used to find suitable areas for specific activities. Using straightforward methods, it is possible to illustrate the impact of a hypothesis and the resultant changes in objectives. Compared to other more intricate knowledge-based techniques such as Multi-Criteria Decision Analysis (MCDA), the PSA approach is simpler and can be employed to spatialize areas for development.

As a result, it was found that the area in front of the University of Phayao, along both sides of Phaholyothin Road (Highway No.1), is suitable for community expansion. This is because the area is close to the original urban community and has sufficient living facilities. Access to the area and service activities is more convenient than in the surrounding areas, making it attractive for densely populated settlements. However, the rapid growth of the community in recent years has led to infrastructure problems, including solid waste treatment, wastewater management, and inadequate power supply [35].

Thus, to address the challenges of enhancing quality of life, boosting wealth, and attaining economic growth the proposal is to promote mixed-use development and design. This approach involves creating a comprehensive and diverse range of activities within a single specified area and region. Such developments frequently encompass a mix of residential, manufacturing, commercial, retail outlets, institutional facilities, educational, and recreational areas. They can range in scale from a single building to extensive, planned communities [36]. The primary objective of mixed-use developments is to minimize travel distances by clustering various activities near one another.

To address the challenges associated with sustainable development, it is crucial to provide a variety of transportation options. This includes efficient public transit, adequate and secure cycling and pedestrian infrastructure, as well as well-preserved bridges and roadways. These measures can help communities attract talent, compete on a global scale, and improve the quality of life for their residents [37]. To achieve this, elected officials and transportation agencies must revise their approaches to prioritizing, selecting, investing in, constructing, and evaluating transportation projects at local, regional, and national levels. Governments can enhance transportation options by revising zoning laws to permit the integration of residential and commercial properties [38], and by directing new developments to locations that are readily accessible via public transit. Additionally, governments can design safe and attractive streets for pedestrians and cyclists, ensuring that connections between various transportation modes such as cycling, bus, rail, and paratransit are seamless and convenient [39].

Protecting environmental areas such as forests, agricultural land, and open spaces can enhance community resilience by shielding them from natural disasters, preventing soil erosion, regulating temperatures, managing air flow, mitigating air quality degradation, protecting water quality and conserving ecosystems [40]. There is a strong interconnection between the environment, quality of life, economic development, and environmental protection [41]. Public participation encourages collaboration between the community and stakeholders in the development process. As each community has unique requirements, addressing those needs requires a unique approach for each place. Stakeholders generally prefer to be engaged in the planning and development process from the outset. Early involvement of stakeholders can offer ongoing creative input, which helps ensure that the development becomes more livable and dynamic for the community, especially if their input is taken into consideration [42]. Communities experiencing disinvestment may need to prioritize downtown development, whereas those with strong economic growth, the focus might shift towards addressing social equity issues. Regardless of the specific challenges, the needs of each community and the strategies to address them are most effectively determined by the residents and workers within those communities [43].

Local governments or policymakers affecting urban development is crucial, as they are responsible for creating policies, regulations, and plans that shape the growth and development of cities and towns. Local governments have the authority to manage land use, transportation systems, and public services, and they play a critical role in ensuring that urban areas are safe, healthy, and vibrant places to live and work [44]. Local governments also use zoning laws to regulate the types of land use allowed in specific areas. For example, zoning laws might limit the construction of high-rise buildings in residential areas or mandate that new developments incorporate a specified proportion of affordable housing. Zoning laws can also be used to mandate the creation of parks and open spaces, which help to enhance the quality of life in urban areas [45]. The policymakers also use the principle of public private partnership in planning that can enhance the effectiveness of public projects by combining resources and expertise from both the public and private sectors. It often leads to better project outcomes and more innovative solutions and involves collaboration between governmental bodies and private sector firms to provide public services or utilities. It typically includes shared responsibilities, risks, and benefits between the public and private sectors.

6. Conclusion

Mae Ka Urban Planning for Sustainable Development, Phayao, Thailand" is a study that examines the physical, economic, and social characteristics of the Mae Ka community,

integrating GIS technology to analyze urban growth. The study LANDST-5 in 2001 and 2011 and Sentinel-2 in 2021 to address land use changes. The results show that from 2001 to 2021, there was an increase in water resources, built-up area, miscellaneous area, and agricultural area by 60.79%, 24.65%, 18.07% and 9.12%, respectively, which is related to urban development and expansion. However, the forested area has decreased by 11.74% due to the urbanization process.

The research also used the PSA method to determine the factors affecting the potential areas for development. The rankings were evaluated based on three main factors, including physical factors, infrastructure factors, and risk area factors. The results displayed four categories of potential with scores of 23.74 square kilometers, 64.39 square kilometers, 55.75 square kilometers, and 132.70 square kilometers for high, moderate, low potential areas, and protected areas, respectively. The high potential areas for promoting urban growth in community centers include commercial, residential, recreational, and educational institutions and are located along Phaholyothin Road (Highway No.1), especially in front of the University of Phayao, Mae Ka subdistrict, Highway No. 120, Phayao-Wang Nuea Road, and Ban Mae Na Rua Tai Mae Na Ruea subdistrict. The moderate potential areas, which are reserved for future urban growth, are vacant green areas and mixed agricultural lands. The areas conserved for agriculture and food production are in rural agricultural and agricultural land reform areas where the concentration is not on economic development. The protected areas, which are reserved for forests and watersheds, are high mountains that preserve and protect forests, wildlife, watersheds, streams, and other natural resources in Mae Tam Forest, Mae Na Ruea Forest, and Mae Tam Forest.

For sustainable development guidelines for Mae Ka urban planning, the plan consists of three proposed plans: land use plan, transportation plan, and infrastructure plan, based on the idea of smart growth. The goal is to achieve: 1) a city with mixed land, adequate basic structures and services that are accessible and appropriate to the capacity of the community, such as housing, clean water, electricity, educational institutions, and hospitals; 2) a city with efficient use of resources and energy, such as green spaces, sustainable land use, energy-efficient management, and sustainable consumption; 3) a city that effectively reduces, controls, and manages waste and pollution, such as wastewater and garbage management and support for clean production technologies; and 4) a city with a competitive economic base that promotes environmentally friendly growth, equal and fair economic development, such as support for environmentally friendly enterprises, sustainable tourism, and equal access to resources.

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