Assessing land use change in the context of climate change and proposing solutions: Case study in Gia Lai province, Vietnam

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Abstract: The study presents the results of the assessment of land use change in the period 2014–2019 in Chu Pah district, Gia Lai province and proposed solutions. The research used the methods including data collection, spatial analysis, stakeholder and expert analysis. Remote sensing imagery (Google Earth) is employed to interpret, and the conducted field survey to verify in 14 communes and towns in order to create the current map of land use with high accuracy. For instance, the group of agricultural land changes the largest with the conversion of annual crop land into perennial crops. The area of residential land increases due to the increasing demand of residential land and the population growth. In addition, the group of unused land decreased relatively high mainly to meet the needs of cultivation and afforestation. The negative impacts of climate change also contribute to change the purpose and status of land resources in Chu Pah district. The results are meaningful in providing database for establishing land use status quo map and making decisions on sustainable socio–economic development.

Keywords: Land use change; Land management; Climate change; Google Earth; Remote sensing.

1. Introduction

Studying land use change is to clarify changes and use land resources effectively in specific areas using modern technologies such as remote sensing and geographic information systems [1–3]. Many studies showed that land cover change is an important factor in environmental change. Therefore, research on land use change is considered by scientists and managers to analyze the causes. In fact, there are many methods of determining the process of land use changes such as applying experimental models to assess changes in land cover by remote sensing [3–6]. However, this approach is unsuccessful in explaining human behavior leading to land use change. According to another approach, spatial modeling can be used to determine the process of land use changes based on the Google Earth satellite images [7–9]. Advantages of using Google Earth can provide high spatial resolution satellite imagery. Google Earth provides images at different times and is therefore very useful in the process of urban planning development and in determining land use and land cover changes. High resolution Google Earth satellite imagery can observe visual objects such as residential areas, construction works, transport systems, water surface, etc. to integrate into GIS to create the current land use map [9]. These changes will then be used to assess impacts related to

policy and other factors. In addition, statistical analysis method is a useful tool due to the ability to test hypotheses, rank factors, test hypothesis rigor. However, the process requires a combination of spatial, temporal and analytical data, so there are still obstacles and challenges to achieving the accuracy results [10].

Chu Pah district is an important gateway in the northern economic corridor of Gia Lai province and Pleiku city. Chu Pah is located in an important position and has exchange advantages to promote local socio–economic development [11]. Meanwhile, the process of economic development and urbanization has caused many problems in the management and use of land resources such as degradation, inappropriate use of resources, and land disputes [12]. According to the scenarios of climate change and sea level rise for Vietnam, compared with the period of time 1980–1999, the average temperature will be increased around 2 to 3°C at the end of this century [13]. Also, with the current negative impacts of climate change in the Central Highlands region is significant. Land use change is a research process related to the way people use land. It alters the availability of various resources including vegetation, soil, and water. Water resources management could be affected by land–use change such as the amount of evapotranspiration, groundwater infiltration and overland runoff [14]. In addition, climate patterns, natural hazards also could be affected negatively on a global and local scale [15]. Climate change is the change of the climate system such as hydrosphere, biosphere and lithosphere by natural and artificial causes. According to research [16] showed that the impacts of climate change have changed agricultural activities. Similarly, the research showed that many areas of Gia Lai province are affected by variations in temperature, precipitation, and extreme weather events such as droughts and floods. In agriculture, there should be many synchronous solutions, in which the change of crop structure needs to be suitable with the weather conditions of the area [17]. There is an urgent problem to be addressed in the state management of land resources.

Therefore, it is important to assess land use change and propose solutions for effective land use and management, providing detailed and accurate information for policy making. At the same time, the results also support the management of rational and efficient use of land resources, meeting the use demands of economic, cultural and security and defense sectors.

2. Methods

2.1. Study area

Located in the north of Gia Lai province, Chu Pah district has a natural area of 97,457.68 ha, bordering Kon Tum province in the North; Dak Doa district in the East; Ia Grai district in the west; Pleiku city and Ia Grai district in the south. Climate characteristics of Chu Pah district are characterized by the Central Highlands, the humid tropical climate of the south Vietnamese monsoon, there is a distinct difference and contrast between the two seasons. The dry season is from November to April each year with low rainfall, and the rainy season is hot, humid, and rainy, from May to October.

2.2. Methods

2.2.1. Secondary data collection

This method is used to collect data and documents including topographic and hydrological maps [18]; Report on the results of the review and adjustment of 3 forest types in Gia Lai province to 2025 and a vision to 2030 and other relevant documents on administrative boundaries [11].

2.2.2. Mapping and spatial analysis

To analyze and determine the spatial change of land use categories in the period 2014–2019, the study used MicroStation V8i software to establish and edit maps based on Google Earth satellite images (Landsat 8, 30x30 m). In addition, the area of land units are calculated by automatic topology using TK Desktop software Version 3.6.

2014   2019   The status quo map 2019

Figure 1. Mapping and status quo map.

For Google Earth satellite image data (*.TIF), the study used as of 2014 and 2019 (Google Earth Engine: A planetary–scale platform for Earth science data & analysis. URL: https://earthengine.google.com), then converted the WGS84 satellite image coordinates to the VN2000 standard map coordinate system. This study used the coordinate transformation between world geodetic system (WGS84) and Vietnam geodetic system (VN2000) for calculating process [19]. The formula converts the pixel's x–coordinate to the longitude and the y–coordinate of a pixel to latitude, using equations (1) and (2), respectively.

$$x = \left[2^{z+7}\left(1 + \frac{longitude}{180} \right) \right] (1); \quad y = 2^{z+7}\left(1 - \frac{1}{2\pi}\log\left(\frac{1 + \sin\left(latitude\frac{\pi}{180} \right)}{1 - \sin\left(latitude\frac{\pi}{180} \right)} \right) \right) (2)$$

In which, x is pixel's x–coordinate to the longitude; y is the y–coordinate of a pixel to latitude; and z is ellipsoidal height. After downloading and merging Google Earth images with Universals Map Downloader version 9.10 software. Google Earth images will be referenced to the MicroStation V8i software using manual image interpretation method based on the satellite image interpretation keypad. Specifically, in order to perform the satellite imagery interpretation process, the study establishes image interpretation patterns and is described in Table 1. These image interpretation patterns are consistent and followed as land management standards.

Table 1. Google Earth imagery interpretation.

Objective	Pattern	Color	Size	Shape	Topographic
Perennial crops		Dark blue, black	Large	Large, very large cluster	Flat or sloping
Stream and river		Bright, milky white	Unstable	Meandering	Lowlands, valleys
Residential land		Green gray	Small	Rectangular, square	Flat land, small slope
Aquaculture land		Blue	Small	Rectangular, square	Flat, sunken
Paddy land		Green	Unstable	Polygons, plots	Low–lying, riverine

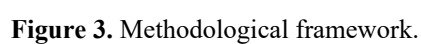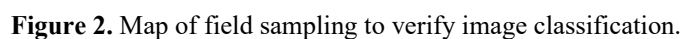| Objective	Pattern	Color	Size	Shape	Topographic
Transport land		Greyish	Unstable	Linear form	Flat, sloping land
Forest land		Black blue	Very large	Very large cluster	Hilly
Water surface		Dark green	Medium, large	Cluster, round shape	Lowlands, lower
Unused land		Red gray	Medium, large	Large, very large cluster	Hilly, large slope

2.2.3. Accuracy assessment

The method of accuracy assessment aims to confirm the accuracy and acceptance of the satellite image interpretation [20–21]. In order to assess reliability, the study conducted field survey and recorded GPS location, and create a matrice to calculate Overall Accuracy and Kappa (K), which is to verify the results of satellite image interpretation [21–22]. Kappa can be used in accuracy assessment and determine the values of error matrix. Kappa is computed as equation (3).

$$K = \frac{N\sum_{j=1}^{r} x_{ii} - \sum_{j=1}^{r}\left(x_{i+} * x_{+i}\right)}{N^2 - \sum_{j=1}^{r}\left(x_{ii} * x_{+i}\right)} \qquad (3)$$

where r is the number of rows of the matrix; x_{ii} is the number of observations of row and column i; x_{i+} and x_{+i} are respectively the marginal totals of row and column i; and N is the total number of observations [22]. In this study, the field survey took 123 random samples of target groups (Figure 2) including perennial crop land (15 samples), stream and river land (9 samples), residential land (9 samples), aquaculture land (12 samples), paddy land (21 samples), transportation land (12 samples), forestry land (15 samples), water surface land (9 samples), and unused land (12 samples). The results of the calculation comparing the satellite image interpretation and the control samples are the basis for evaluating accuracy of the study.

2.2.4. Stakeholder and expert analysis

To clarify the level of stakeholders' involvement in the process of implementing the research to propose land resource use and management solutions, the study determines the approaches for the cooperation and participation of stakeholders [23–24]. After collecting secondary data, a list of stakeholders is fully listed. Following the semi–structured interview method with staff, leaders involved in managing land use change. Next, potential stakeholders were identified, and then conducted semi–structured interviews of experts. A final list of stakeholders is used to classify. Based on the stakeholder power–interest matrix, the stakeholders were subsequently divided into four basic groups including Keep informed, Maintain interest, Active consultation, Key players. After classifying stakeholders, it is important to decide how to involve the stakeholders. Stakeholder analysis clarified the roles and functions and interactions between the parties. This method is significant in making the appropriate solutions recommendation [25–26]. In addition, to solidify the basis of proposing solutions for effective land for resource use management, the research conducted an expert interview based on the Likert scale [27]. Accordingly, the group of experts is explored and will evaluate the score of choosing the solutions based on professional knowledge and experience. Thus, the making solutions are proposed based on the methodological framework and is shown in Figure 3.

Figure 2. Map of field sampling to verify image classification.

Figure 3. Methodological framework.

2.2.5. Statistical method

The data are calculated average (mean), standard deviation (SD) and analyzed using the softwares of M. Excel 2013 and SPSS V.13.0 for Windows.

3. Results and discussion

3.1. Land use change in Chu Pah district in the context of climate change

3.1.1. The current status of land use change

The use of satellite imagery (ie., Landsat 5, 7 and 8) from Google Earth demonstrations the effective application in processing and assessing changes in land resources [7] by the spatial interpretation and analysis. In 2019, the area of natural land in Chu Pah district was 97,221.37 ha, lower than that in 2014 (97,457.68 ha) with the decline of 236.30 ha (Figures 5 and 6). The reason is due to the change of administrative boundaries between Gia Lai and Kon Tum provinces, which was determined according to Resolution No. 113/NQ–CP [28].

3.1.2. Change of land use categories

In 2019, the results illustrate that agriculture land was 86,160.44 ha and witnessed an increase of 1,085.22 ha (an average rise of 217.04 ha/year, corresponding to the rate of 0.25%/year) in the period 2014–2019 (Table 2). Obviously, the negative impact of climate change has caused difficulties for human activities such as the poor, vulnerable communities in rural areas [18, 29]. This is a hug reason lead to change of land use in developing countries as Vietnam. The results found the highest increase is perennial crop land with 9,120.62 ha from annual crop land and unused land in the communes of Ha Tay, Ia Khuol, Ia Mo Nong and Ia Ka. In addition, the area of forest land increases 1,224.21 ha due to the area of planted forests in Ia Ly protection forest management unit (subdivision 215–Ia Kreng Commune) and Bien Ho protection forest management unit (subdivision 253–Hoa Phu commune). The current situation of rice land changes showed an increase of 329.30 ha due to the adjustment of paddy land along rivers and streams for the effective management and use of land resources in the communes of Ha Tay, Ia Khuol, and Ia Mo Nong. It can be seen that the assessment of the current state of changes in agricultural land resources plays an important role in proposing solutions to the effective management and use of local resources.

Table 2. Changes in agricultural land in the period 2014–2019.

ID	Land use categories	Area (ha)		Change (ha)	Rate (%/year)
		2019	**2014**		
1	Paddy land	4,657.97	4,328.67	+329.30	+1.41
2	Annual crop land	13,440.22	21,990.47	–8,550.25	–12.72
3	Land for perennial crops	38,339.22	29,218.60	+9,120.62	+4.76
4	Forest land	29,541.67	29,391.35	+150.32	+0.04
5	Aquaculture land	150.28	115.28	+35.00	–0.05
6	Other agricultural land	31.10	30.85	+0.25	+4.66
	Total	86,160.44	85,075.22	+1,085.22	+0.25

Figure 4 shows the fluctuation of non–agricultural land group in the period 2014–2019 in Chu Pah district. Notably, residential land increased by 22.44 ha, corresponding to an increase of 0.56%/year due to the needs of infrastructure development in the context of rapid population growth. The results show similarities with previous studies on the causes of urban expansion in the Central Highlands [30].
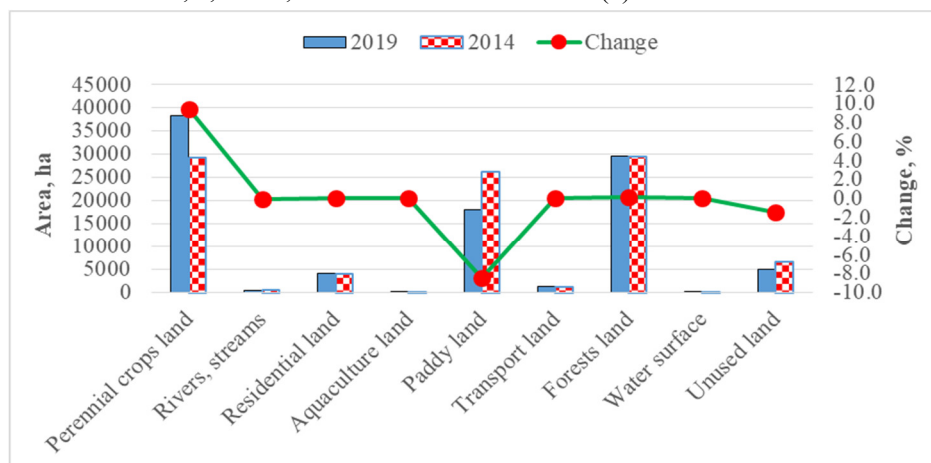
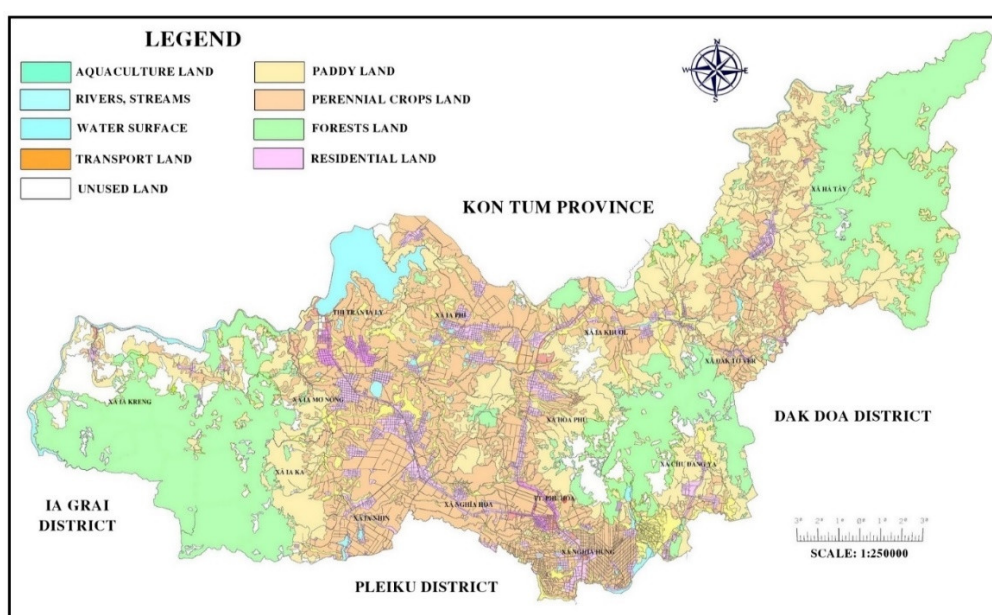**Figure 4**. Changes in agricultural land in the period 2014–2019.

Figure 5. Current land use map in Chu Pah district in 2014.
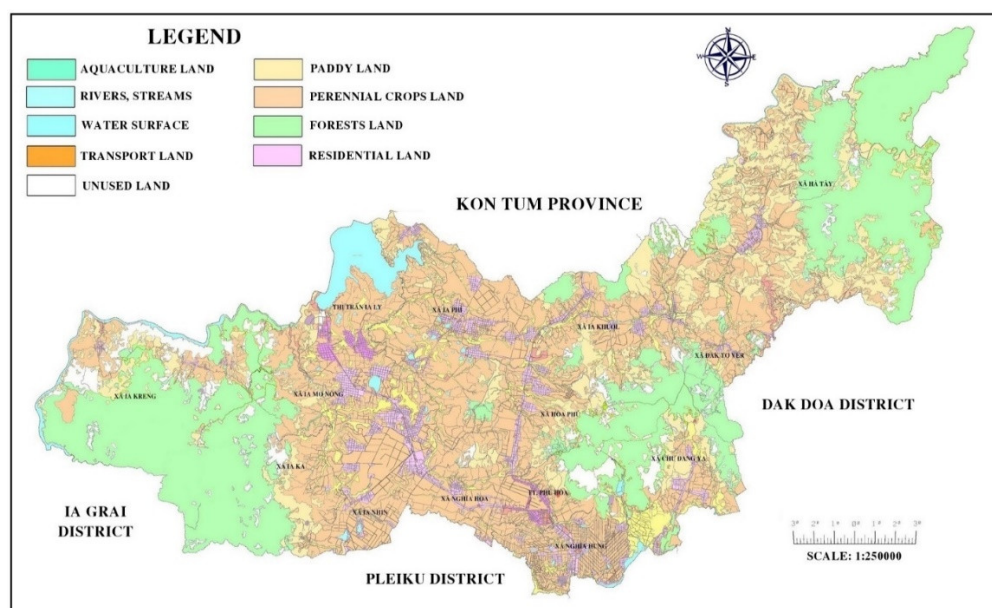

Figure 6. Current land use map in Chu Pah district in 2019.

3.1.3. Evaluate the reliability

Evaluating the reliability of satellite imagery interpretation has an important role and confirmed the acceptability levels [30–31]. During random field sampling, matrix studies compute the accuracy level through Overall Accuracy and Kappa's index. Table 3 shows that the accuracy level in the image classification process is high with the lowest rate corresponding to 75.0% (for example: aquaculture land, unused land). In contrast, the groups such as residential land, transportation, rivers and streams have very high accuracy. Normally, the accuracy of over 75.0% Google Earth satellite image interpretation is satisfactory and acceptable. In this study, the Overall Accuracy was 87.8% and Kappa index was 86.3% represents high reliability. Thus, the results of the study showed that the Overall Accuracy in the process of creating land use maps of Chu Pah district and the Kappa index is acceptable. It can be seen that the imagery interpretation process to assess land use change in Chu Pah district is effective and meets the criteria of imagery classification.

Table 3. Matrix of accuracy evaluation after imagery classification.

Land classify	Field–proven by GPS									Sum
	Perennial crops land	Rivers, streams	Residential land	Aquaculture land	Paddy land	Transport land	Forest land	Water surface	Unused land	
Perennial crops land	12	0	0	0	3	0	0	0	0	15
Rivers, streams	0	9	0	0	0	0	0	0	0	9
Residential land	0	0	18	0	0	0	3	0	0	21
Aquaculture land	0	0	0	6	0	0	0	0	0	6
Paddy land	0	0	0	0	18	0	0	0	3	21
Transport land	0	0	0	0	0	12	0	0	0	12
Forests land	3	0	0	0	0	0	12	0	0	15
Water surface	0	0	0	3	0	0	0	9	0	12
Unused land	0	0	0	3	0	0	0	0	9	12
Sum	15	9	18	12	21	12	15	9	12	123

3.2. Analyze stakeholders and propose effective management solutions

Stakeholder analysis is a useful tool based on a coordinated and supportive approach to sustainable land resource management [32–33]. In this study, the matrix would examines the interest and influence with 3 levels (low–medium–high), which are classified into 4 groups (Figure 7).
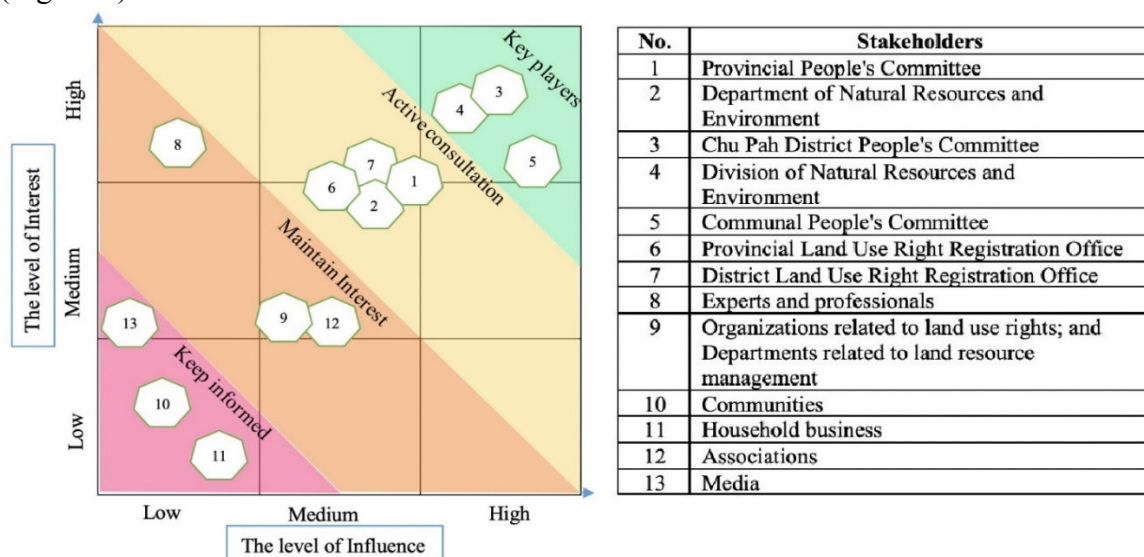

No.	Stakeholders
1	Provincial People's Committee
2	Department of Natural Resources and Environment
3	Chu Pah District People's Committee
4	Division of Natural Resources and Environment
5	Communal People's Committee
6	Provincial Land Use Right Registration Office
7	District Land Use Right Registration Office
8	Experts and professionals
9	Organizations related to land use rights; and Departments related to land resource management
10	Communities
11	Household business
12	Associations
13	Media

Figure 7. Matrix of stakeholder analysis.

The process of analyzing stakeholders specifically classifies: (i) The group of key stakeholders that are direct participants (high level of importance and influence) includes: The Division of Natural Resources and Environment is a specialized agency to advise and assist the Chu Pah District People's Committee in performing the state management function in the field of natural resources and environment; At the commune level, cadastral and environmental officers are responsible for advising and performing tasks to assist the communal People's Committee to organize the implementation in the fields of land use management, environmental resources, construction, urban, transport, agriculture; (ii) A group of stakeholders that requires proactive consultation (medium to high impact and low to moderate interest) including the Department of Natural Resources and Environment to advise and assist the Provincial People's Committee and coordinating with the Land Use Right Registration Office at the provincial and district level); (iii) A group of stakeholders that need to maintain an interest (medium to high level of interest, low influence) including experts and professionals (consultants, expert advisors, policy); organizations related to land use rights; and departments related to land resource management; (iv) A group of stakeholders who should exchange information (low interest and low influence) including residential communities, household business, and media.

On the other hand, based on the current situation as well as the analysis and grouping of stakeholders, combine with expert survey in the context of climate change, the study proposed some solutions for effective land use resource management in Chu Pah according to the priority categories.

Table 4. Proposal on solutions for efficient management and use of land resources.

Code	Recommended solution	Values[1]	Ranking
GP_1	Develop and implement programs to support sustainable livelihoods, stabilize life and economic development.	4.724±0.578	I
GP_2	Strengthen inspection and supervision of the use of land resources; strictly handle violations of approved land use plannings.	4.451±0.285	II
GP_3	Investment in the documents for land resource management such as cadastral mapping, certificate of land use rights.	4.037±0.963	III
GP_4	Policy of improving unused land resources, improving the efficiency of agricultural and forestry land exploitation to meet development needs in the sustainability and protection of the ecological environment.	3.831±0.321	IV

Notes: $GP_{1–4}$: Solutions from 1 to 4. [1]Values: Mean±SD of 5–point Likert scale.

In general, strengthening sustainable land use management should be aimed at using land ecology efficiently [34], thereby contributing to reducing the global consequences in the exploitation and use of land resources [35]. Survey results with priority order: developing and implementing a sustainable livelihood support program > monitoring the implementation of land use > developing documents for resource land management resource > improving unused land resources and the efficiency of agricultural land exploitation. In which, the average value of the expert assessment is to build and implement the sustainable livelihood support program (GP_1) with the highest result of 4.724 (SD = 0.578). Similarly, the solutions of GP_2, GP_3, GP_4 with the average values are 4.451 (SD = 0.285); 4.037 (SD = 0.963) and 3.831 (SD = 0.321) respectively. Therefore, it is recommended to pay attention to solutions to improve the efficiency of agricultural and forestry land exploitation in order to meet the needs of sustainable development and protection of the ecological environment.

4. Conclusions

The results of applying Google Earth satellite imagery interpretation approach to establish land use maps help illustrate the distribution of land–use space in Chu Pah district. The Overall Accuracy and Kappa index were respectively 87.8% and 86.3%, representing

high reliability. From our study of the land use changes in Chu Pah district showed that the conversion from annual crop land into perennial crop land was outstanding in the period 2014–2019. Analysis of the use of non–agricultural land groups can be seen that the residential land area has increased significantly (22.44 ha) to serve the needs of transforming economic development and responding to population growth. In addition, the negative impact of climate change can be caused change of land use in developing countries. The negative impact of climate change has been caused difficulties for human as well as agricultural activities in Chu Pah district. The results also found that the cooperation and participation of stakeholders is the foundation for effective management of land resources use on the basis of accountability and coordination. In order to limit the situation of self–conversion of land use categories not according to planning the specialized agency should consider relevant recommendations. However, limitations of the current study can be existed by the pixels in the affected highland areas, which cannot be detected as well as other zones (e.g. plain areas). The difference between this study and land inventory status quo might be occurred in the small scope. In the future, we should be used the higher–resolution images to investigate these changes.

Author contributions: Constructing research ideas: N.N.H., N.T.A.; Select research method: N.T.A., N.N.H., N.M.K.; Survey, sampling and analysis: N.N.H., N.T.A., N.M.K., N.H.D.M., N.T.L., N.T.N.H.; Data processing: N.N.H., N.T.A., N.M.K., B.Q.D.; Writing– original draft preparation: N.N.H., N.T.A., N.M.K.; Writing–review and editing: N.N.H., N.T.A., N.M.K., B.Q.D.

Conflicts of Interest: The authors declare no conflict of interest.

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