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公益財団法人富山第一銀行奨学財団
理事長　野村　充　殿

助成研究成果概要報告書

教育機関名　：University of Toyama	助成金額　：　800　千円	
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研究題目：　Assessing and predicting the challenges and uncertainties of rice cultivation in Toyama Prefecture, Japan （日本・富山県における稲作の課題と不確実性の評価および予測 ）		

研究概要

気候変動と地球温暖化は気象パターンを変化させ、作物の生産性を脅かしています。その結果、食料不安が生じる可能性があります。日本の水田は、気候変動や社会経済的要因による多面的な危機により、不安定な状況に置かれている。リモートセンシングと MaxEnt 予測モデリング手法を活用して衰退しつつある水田を特定することは、農業の潜在能力を大幅に高め、地域における統合的かつ地域密着型の持続可能な管理に向けた適切な解決策を提供する。この手法は、主な要因を特定することで、気候変動や社会経済的状況に起因する水田の放棄の可能性を示唆するものである。本研究は、富山県氷見市における食料安全保障に向けた政策的に意義のある地域密着型の解決策を提示するため、水稲栽培のシナリオ、課題、および不確実性を探求することを目的としている。土地利用・土地被覆分析によると、富山県氷見市では 2000 年から 2025 年にかけて水田が 590 ヘクタール減少した。その結果、夏季の降水量と平均気温、および農業従事者数が水田の放棄分布に影響を与える主要因であり、これら 3 要因の累積寄与度は 70%を超えていることが示された。水田は北西方向に向かって減少すると予想されており、水田が減少する可能性が高い地域は 733 ヘクタールと予測される一方、さまざまな脆弱性の範囲による減少総面積は 2392 ヘクタールに上る。この水田の減少および将来予想される減少は、ヒミ市の稲作にとって潜在的なリスクとなる。気候変動が稲作に適応する上で及ぼす影響を緩和するための今後の取り組みには、播種時期の変更、品種の改良、および肥料の合理的な施用が含まれるべきである。これらの適応策は、農村振興の取り組みを推進し、持続可能な社会環境および農業開発の統合的な進展を促進するために極めて重要である。本学際的研究は、持続可能な開発目標（SDGs）のターゲット 13（気候変動対策）および、飢餓の撲滅、食料安全保障の達成、栄養状態の改善、持続可能な農業の推進を目指す SDG 2 への貢献を目指している。

(In English)

Climate change and global warming are altering weather patterns, threatening crop productivity. The resultant impact can be food insecurity. Japan's rice farms are in a precarious situation due to a multifaceted crisis driven by climate change and socio-economic factors. Utilizing remote sensing and the MaxEnt predictive modeling approach to identify declining rice fields can significantly enhance agricultural potential and provide a pertinent solution for integrated, place-based sustainable management in the regions. This technique suggests the likely abandonment of rice fields owing to climate change and socio-economic context by identifying the principal factors contributing. The research aims to

explore rice cultivation's scenarios, challenges, and uncertainties to bring policy-relevant, place-based solutions for food security in Himi City, Toyama Prefecture, Japan. The land-use and land-cover analysis shows that rice fields have decreased by 590 ha from 2000 to 2025 in Himi City. The results indicate that summer precipitation and mean temperature, along with the number of agricultural management people, are the primary factors influencing the potential abandonment distribution of rice fields, accounting for a cumulative contribution of >70%. Rice fields are expected to decline northwestward, and the high probability for declining regions of rice fields is predicted to be 733 ha, while the total area of decline due to various ranges of vulnerability comprises 2392 ha. This decrease in rice fields and the probable future decrease present potential risks for rice cultivation in Himi City. Future efforts for mitigating the effects of climate change on rice planting adaptation should include sowing period changes, cultivar innovation, and rationalized application of fertilizer. These adaptable solutions are critical for advancing rural revitalization initiatives and promoting the integrated advancement of sustainable socio-environmental and agricultural development. This multidisciplinary research seeks to contribute to Target 13 (climate action) of the Sustainable Development Goals (SDGs) and SDG 2, which aims to eradicate hunger, achieve food security, improve nutrition, and promote sustainable agriculture.

成果要約

Land use land cover (LULC) change detection in Himi city

LULC classification for Himi, Toyama, was accomplished to evaluate environmental changes between 2000 and 2025. Figure 1 illustrates the LULC maps of Himi city for 2000 and 2025. This map shows the comparison of the land types in the study site by six LULC classes (Table 1). Yellow is for rice fields, green colors for vegetation cover, blue color for water bodies, gray for other types of vegetable and/or non-perennial crops (i.e., barley, tomato, soybean, corn, etc.), and bare land, and brown color for built-up areas. The overall area of Himi city was 230.56 ㎢, from where the built-up area decreased by 999 ha from 2993 ha. Deciduous forest, orchard, and shrub areas increased by 3839 ha from the year 2000 to 2025 (Table 1). The potential reasons behind the decrease in built-up areas include depopulation and settlement abandonment. A number of agricultural lands or rice fields were converted into plantations, orchards, and abandoned by growing shrubby vegetation, which led to an increase in deciduous forest, orchard, and shrub area. On the other hand, water bodies have decreased by 3.5 ha, and rice cultivated land has decreased by 590 ha because of the abandonment of rice cultivated fields and conversion to orchards due to depopulation and shortage of agricultural labor. This current study shows that rice cultivated land has decreased from 2450 ha to 1860 ha between 2000 and 2025, respectively, which is comparable to the crop statistical survey's estimate of a decrease from 2230 ha to 1580 ha between 2000 and 2024 (MAFF 2025). The ridge between plots and access roads to the rice field was included in the LULC of rice cultivated land classification analysis. Additionally, the imagery collected in the months of June-July provides a precise estimation of LULC, which aligns with the rice cultivation period.

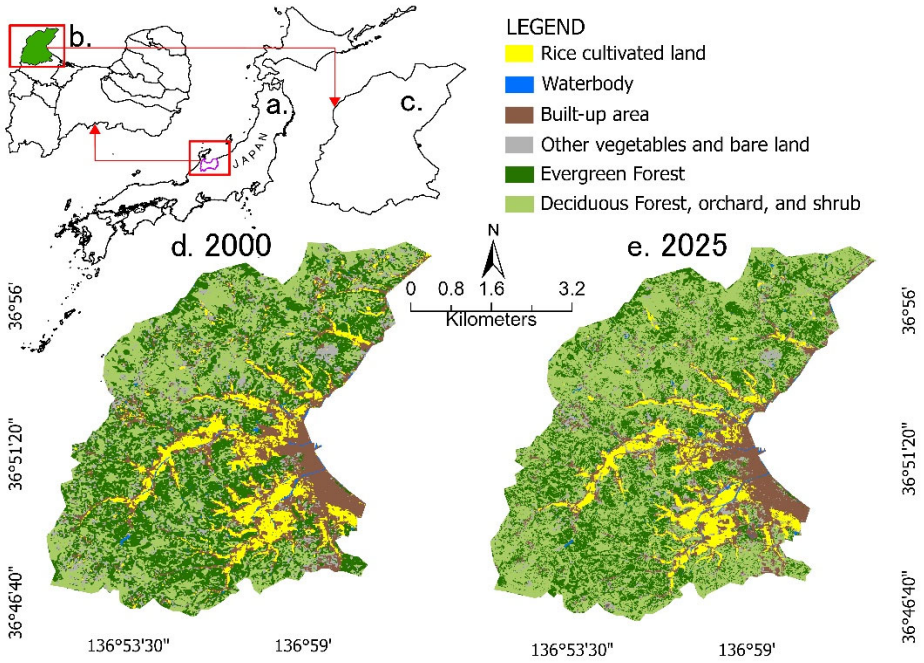

Figure 1: LULC classification map of Himi city, Toyama, Japan. In this map, a. represents the boundary of Japan, b. boundary of Toyama Prefecture showing Himi City, c. boundary of Himi City, d. the left side map represents the year 2000, and e. the right side represents the year 2025.

Table 1: LULC classification table and area statistics of Himi city, Toyama, Japan. The characteristics of land feature types of the existing LULC are provided in the table in the Remarks column.

LULC Class	Area in 2000 (ha)	Area in 2025 (ha)	Remarks
Waterbody	132.4287	128.8441	Lake, ponds, ditches, canals, and rivers
Deciduous forest, orchard, and shrub	6561.214	10401.09	Plants dropping leaves with seasonal variations, orchards, and shrubby plants
Evergreen forest	8546.382	6930.839	Plants retain green leaves throughout the year
Rice cultivated land	2450.291	1860.787	Land under rice cultivation, ridge between plots, and access roads to the rice field
Built-up area	2993.826	1994.479	Settlements, road networks, and other commercial and industrial built-up areas
Other vegetables and bare land	2400.605	1768.072	Non-perennial crops (barley, tomato, soy, corn, etc.) and bare land

A stratified random sample technique has been used for both 2000 and 2025 to assess accuracy. For each LULC class in Himi City between 2000 and 2025, 40 validation samples were chosen, totaling 240 reference points. Strong agreement between the categorized map and reference data was demonstrated by the classification's overall accuracy of 87.5% and 94.17%, respectively, with a κ *coefficient* of 0.85 and 0.93 for the years 2000 and 2025.

The following 15 local key areas were selected to predict the future trends of rice fields based on the substantial rice field abandonment, i.e., Shinbo, Ron-den, Okubo, Tae, Hayakashi, Ogume, Hizume, Hinata, Mio, Tokonabe, Kuzuba, Kume, Furezaka, Iwase, Miuchi. The LULC classification analysis was conducted before conducting MaxEnt modeling in these 15 local areas (Figure 2). The comparative results reveal significant shifts in the landscape. Most notably, Rice cultivated land areas showed a substantial decline, dropping from 250 ha to 206 ha from the year 2000 to 2025 (Table 2). Other vegetables or non-perennial crops (barley, tomato, soy, corn, etc.) and bare land have also undergone a decrease of around 43 ha, suggesting potential land abandonment or preparation for development activities. Conversely, deciduous forests, orchards, and shrub areas experienced a sharp increase, growing from 719 ha to 1221 ha, suggesting potential land abandonment leading to the rise of shrubby vegetation and the establishment of other deciduous forest species and orchard plantations. Evergreen forest perceived a reduction of 286 ha because of industrial developments, population aging, and the abandonment of traditional management. Lack of human intervention (coppicing/thinning) has led to unmanaged forests as rural populations decline, allowing for rapid, unmanaged succession (Ministry of the Environment Government of Japan 2010).

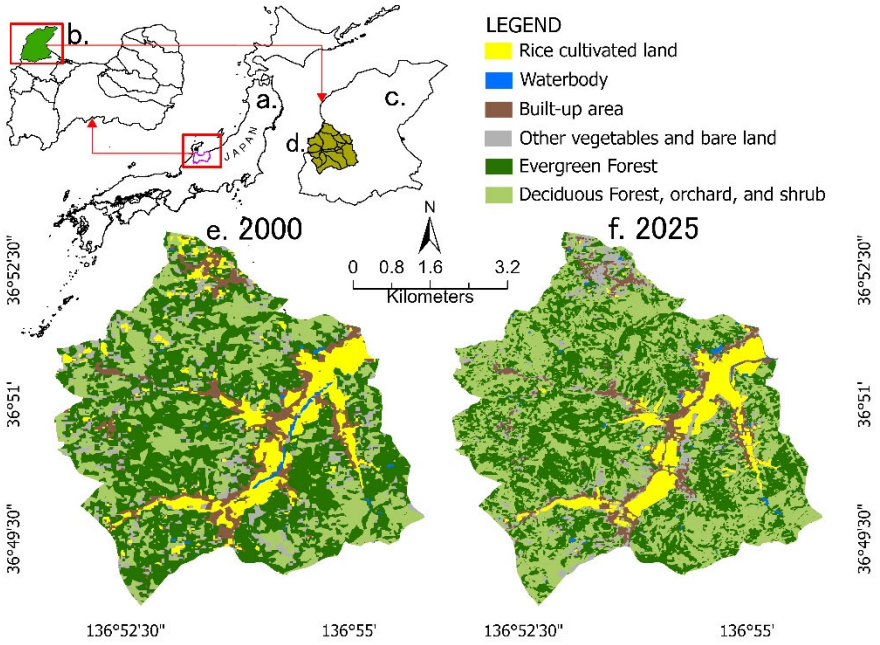

Figure 2: In this map, a. represents the boundary of Japan, b. boundary of Toyama Prefecture showing the Himi City, c. Himi City showing selected regions, and d. selected regions inside Himi City, e. the LULC maps of the selected area in 2000, and f. 2025.

Table 2: LULC classification table and area statistics of 15 local areas in Himi city, Toyama, Japan

LULC Class	**Area in 2000 (ha)**	**Area in 2025 (ha)**
Waterbody	14.96	9.53
Deciduous forest, orchard, and	719.89	1221.52

shrub		
Evergreen forest	1362.69	1076.02
Rice cultivated land	313.80	228.13
Built-up area	205.24	125.13
Other vegetables and bare land	250.37	206.91

Note: See Table 1 for the characteristics of land feature types of the existing LULC in the Remarks column.

Based on the resulting confusion matrix of the *Kappa coefficient (κ)*, the classification achieved an overall accuracy of 88.33% in 2000, with a *κ coefficient* of 0.86, indicating strong agreement between the classified map and reference data. In 2025, the accuracy assessment results showed an overall accuracy of 93.89% and a *κ coefficient* of 0.92.

Prediction of probable rice field scenario using Maxent modeling

The Maxent model output shows an enlarged area of rice field decline or abandonment than the existing area. The output range of the modeling result varied from 0 to 1. The value near zero means lower susceptibility, and the value near one means higher susceptibility. The warmer color shows the area of higher vulnerability to abandonment of the rice field. The average AUC is 0.75, which represents the rational and acceptable accuracy of the model (West et al. 2016).

Figure 3 shows the prediction scenario of rice field abandonment in Himi city using Maxent modeling. The predicted area was classified into four classes. The lower susceptible area ranged up to 0.243, the medium susceptible area ranged from 0.244 to 0.392, the medium-high area ranged from 0.392 to 0.53, and the highly susceptible area ranged from 0.531 to 0.86. The high vulnerability areas are yellow in color, and the low vulnerability areas are dark blue in color. Figure 3 showed that most of the north-western parts of the area are at high risk of abandonment.

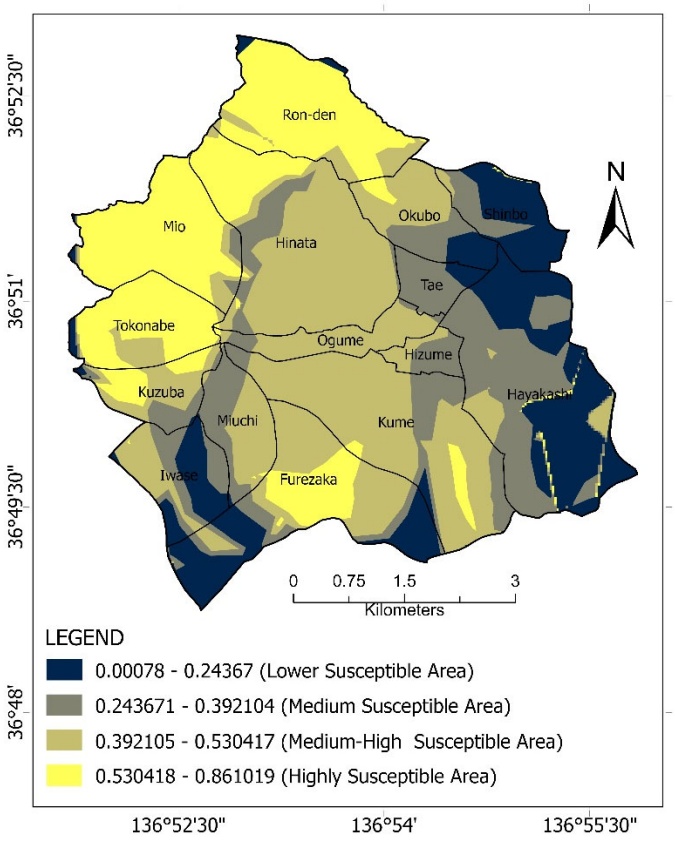

Figure 3: Prediction scenario of rice field abandonment in Himi city using Maxent modeling. The area includes 15 selected local regions of Himi city, Toyama. The lowest probable decline of the rice field displayed dark blue in color. The highest susceptible area of decline is shown in yellow.

The highly vulnerable areas that fall under the great risk of probable abandonment are Ron-den, Mio, Tokonabe, and part of Kuzuba and Furezakaa, including a small part of Kume and Okubo, which comprise an area of 733 ha. The major causes of probable decline in this area are high-altitude forested areas, which are primarily far from the locality. A few dissected settlements were found in this area, where some are abandoned. The medium-high and medium ranges of probable threat to decline include mostly Ogume, Kume, Hinata, Okubo, Kuzuba, and most of the Miuchi area, comprising approximately 1660 ha. This region is located primarily in the central part of the study area and near the settlements associated with forest cover. On the other hand, the less vulnerable area consists of Shinbo, Tae, Hayakashi, part of Iwase, and a small part of the Furezaka area. The total area of decline due to various ranges of vulnerability comprised 2392 ha, coupled with contemporary functional agricultural land.

Contribution of climatic variables and their response curves to the model

The following table (Table 3) gives estimates of the relative contributions of the environmental variables to the Maxent model. The highest contributing climatic variable is precipitation for summer, contributing > 27%. The second contributing variable is the socio-economic variable of the number of agricultural management people, which contributes > 25%. Mean temperature (°C) for summer and mean maximum

temperature (°C) for summer combinedly contribute > 27.5%. Precipitation for spring (mm) and senior-aged people has a lower contribution of less than 10% influence on the rice field abandonment. Precipitation for summer (mm) has the highest permutation importance of 27.2. The second and third permutation importance were 26.9 and 19.4, respectively, for the variables of Mean maximum temperature (°C) for summer and the number of agricultural management people. The fluctuation or changes of these variables may cause variations or further decline in rice fields in the future years.

Table 3: Relative contributions of the environmental variables to the Maxent model

Variables	Percent contribution	Permutation importance
Precipitation for summer (mm)	27.8	27.7
Number of agricultural management people	25.5	19.4
Mean temperature (°C) for summer	17.1	10
Mean maximum temperature (°C) for summer	10.7	26.9
Precipitation for spring (mm)	9.7	13.2
Senior-aged people 65+	9.1	2.8

The response curves in Figure 4 show how each environmental variable influences the Maxent prediction. Precipitation for summer has the strongest influence on the model when the value is 587 to 596 mm, with a concave trend of effects and some fluctuations. Precipitation for spring (mm) constantly impacts the model output when the range is 439 to 442, with fluctuations inside the graph from the value 436-438 (Figure 4). The socio-economic variable for senior-aged people 65+ has a continual impact on the model when the number is 20-125. The impact of senior-aged people is higher when the number increases to 130-155, which means the land abandonment is susceptible to increasing along with the increase of senior aged people. Mean temperature (°C) for summer shows the regular trend in the model, except that >25(°C), where there is a sharp vertical increase in the line. Mean maximum temperature (°C) for summer exhibits a concave pattern of influence on the model, with an increase in line at ≧29. The number of agricultural management people demonstrates that the likelihood of land abandonment decreases with increasing numbers.

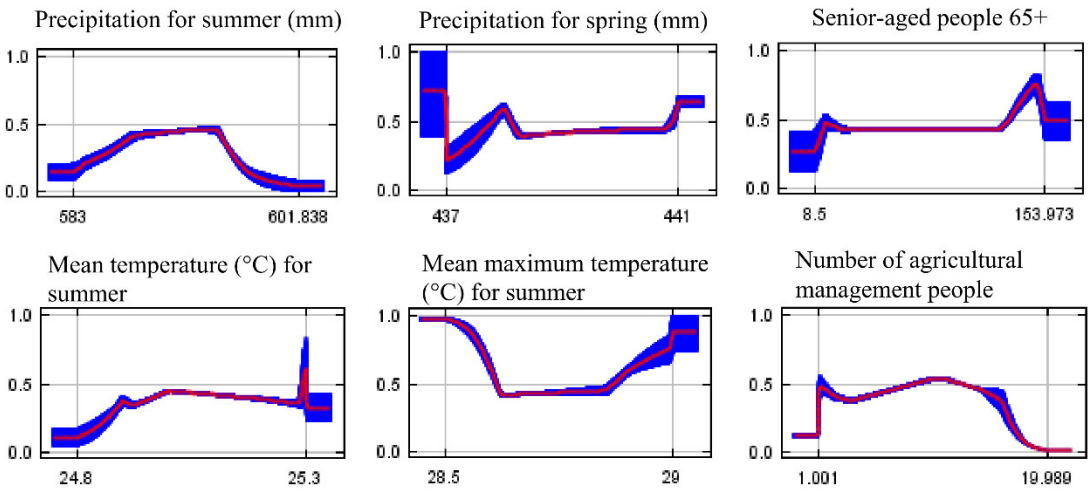

Figure 4: Response curve of the six variables in Maxent modeling. The mean response (red) and mean +/- one standard deviation (blue, with two shades for categorical variables) are represented by the curves.

The LULC results of this study exhibited that the rice cultivated land area has decreased from 2450 ha to 1860 ha in the study area, which represents the direct socio-economic influences of a lack of agricultural workers due to depopulation and aging of the society. On the other hand, the MaxEnt prediction modeling depicted that precipitation and mean temperature for summer have the highest contribution to the rice field abandonment in the near future, which determines the impacts of climatic factors on it. According to the results, this study concludes that the socio-economic and climatic factors are combinedly impacting the rice field abandonment in the study area. Moreover, the high-risk "hot spot" areas of rice field abandonment were stated as medium-high and high susceptibility by the predictive modeling. These findings will support policymakers, professionals, or locals to concentrate and take measures on further revival of the rice-cultivated area in the assessed study sites. The findings of this research recommend that specialists and government bodies focus on the protection of rice fields abandonment based on the contributing factors. Further research is required to predict the future trend based on the in-depth socio-economic conditions. Overall, the MaxEnt-based results showed that sustainable land-use planning requires place-based, climate-informed adaptation techniques. Decision-makers can improve resilience, protect biodiversity, and minimize maladaptive land-use change under persistent climatic pressure by coordinating development constraints, ecological restoration, and agricultural support with locally dominating environmental factors. Despite the above concluding remarks, this study is limited to a small rural area, which limits its generalizability.

References

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West AM, Kumar S, Brown CS, Stohlgren TJ, Bromberg J (2016) Field validation of an invasive species Maxent model. Ecological Informatics 36:126-134, ISSN 1574-9541. https://doi.org/10.1016/j.ecoinf.2016.11.001.

研究成果発表状況	雑誌論文、学会発表、図書、新聞掲載、作成 Web ページ、特許権等の出願・取得状況		
	雑誌論文: Shishir, S., Mollah, N. 2026. Assessing and predicting the challenges and uncertainties of rice cultivation in Toyama Prefecture, Japan. Environmental Systems Research, https://doi.org/10.21203/rs.3.rs-8736594/v1. (accepted on 28 March 2026). https://submission.springernature.com/submission-details/bf848f07-835f-4928-9dbe-15e145ead302) 学会発表: Presented in the international conference of 'NERPS conference 2026' in The United Nations University Tokyo from March 4-6 (https://nerps.org/nerps-2026-japan/)		
経費の執行状況	区　分	執行額(円)	備　考
	【Equipment/Materials（物品費）】 ・Personal computer set (パソコンセット) ・Satellite data (衛星データ) ・ArcGIS software (ArcGIS ソフトウェア)	 403,620 108,570 99,000	PC and ArcGIS software for data analysis, satellite data of the selected study area of Himi city, Toyama
	【Travel Expenses（旅費）】 ・Field survey (公務外出) ・Academic Conference (NERPS 2026, Tokyo) 学術会議（NERPS 2026、東京）	 2,300 135,752	 ・Toyama – Himi ・NERPS 2026 参加費 and accommodation and other expenses (国連大学)
	【その他】 ・English language editing service (英文校正サービス) ・Miscellaneous (その他)	 44,898 5,860	 ・English language proofread ・Necessary items for research (pen, notebook, multiplug, etc.)