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RICE AREA AND PRODUCTION ESTIMATES FOR THE 2022 MONSOON SEASON

Myanmar Agricultural Crop Yield Estimation Project

February 2023

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EXECUTIVE SUMMARY

This report includes a comprehensive analysis of unbiased rice area estimations for the major monsoon rice-producing regions Ayeyarwady, Bago, Kayah, Kayin, Magway, Mandalay, Mon, Rakhine, Sagaing, Shan, and Yangon. The ADPC team performed satellite image classification and high-resolution satellite data interpretation to estimate the total cultivated rice area, including the uncertainty associated with that number. The team combined the area estimations with yield information from the International Food Policy Research Institute (IFPRI) collected via telephone surveys across different regions in Burma. Moreover, ADPC analyzed the spatial and temporal distributions of rainfall over the country and its major river basins.

Generally, the rainfall for the 2022 monsoon was average in quantity but erratic in distribution over time. For the coastal regions of Ayeyarwady, Bago, Mon, and Yangon, ADPC found a higher-than-average rainfall deficit for June and a moderate rainfall deficit for July. However, the larger-than-usual rainfall at the end of the season made up for the difference. Magway showed a deficit for all but one month of the growing season. Rainfall conditions were good for Mandalay in May but below average in the months following. Sagaing showed plenty of rainfall in May and June but below-average rainfall in the three months following. Shan showed higher-than-average rainfall for two months, Kayan for three months, and Kayin for four months. However, total rainfall deficits over the year remained relatively low for most regions except Rakhine, even though Rakhine got some flood impact in the coastal area caused by heavy rain and typhoon in August and October, 2022 —but the data showed a rainfall deficit in Rakhine for all months of the season summing to a total deficit of 600 mm.

Ayeyarwady is the largest rice-producing region and accounted for 28 percent of the total rice area in the country last year. For 2021, ADPC estimated a total area of 1,043,045 hectares (ha), whereas this year, the team found an increase of 8 percent to 1,126,480 ± 61,956 ha[1]. This number is lower than the number reported by the General Administration Department (GAD) for 2020, which was 1,384,321 ha. In addition, ADPC found a large decline of 71 percent for deepwater rice in Ayeyarwady, from 353,247 ha last year to 102,258 ± 33,541 ha this year. According to IFPRI, rice yields decreased slightly from 2.82 to 2.81 t/ha this year in Ayeyarwady, which led to an overall increase in total rice production to 3,165 ± 174 tons per hectare (t/ha) compared to last year's 2,941 t/ha.

Bago, the second-largest rice cultivation region, also grows both rice and deepwater rice. ADPC found a decrease of 6 percent for rice area from 854,024 ha in 2021 to 805,767 ± 43,511 ha in 2022. Both numbers are lower than the 990,183 ha figure reported by GAD for 2020. Deepwater rice also substantially decreased from 44,246 ha in 2021 to 14,190 ± 695 ha in 2022. IFPRI reported a decline in yields from 3.32 to 2.97 t/ha for Bago, which resulted in an overall decrease in rice production from 2,835 thousand tons to 2,393 ± 129 thousand tons. This change represents a 16 percent decline from last year.

Rice cultivation in Sagaing requires particular attention due to aggravated conflict and the region's ability to obtain water for irrigation. Last year, ADPC found that 590,745 ha were cultivated compared to the 641,618 ha reported by GAD. This year, the team estimated a total area of 580,680 ± 25,550 ha of cultivated rice, representing a decline of about 2 percent

[1] ± (ha) range of statistical uncertainty area estimation.

from last year. The IFPRI yield data show a decrease in cultivation from 3.47 to 3.13 t/ha compared to the previous year, leading to an overall decline of 11 percent from 2,050 thousand tons last year to 1,818 ± 80 thousand tons this year. More in depth assessment about rice cultivation in the Shwebo delta shows that production was stable in 2022 compared to 2021. Even though conflict is increasing in Sagaing, this indicates that farmers in the Shwebo areas have maintained rice production despite their difficult situations. There were some small areas of Sagaing where production was non-existent, presumingly because of especially intense conflict in that area. Thus overall, rice production in Sagaing region was surprisingly resilient, with acreage maintained and most of the decline in production due to lower yields.

Rice cultivation in the coastal regions of Mon, Rakhine, and Yangon shows a mixed pattern. ADPC found a 2 percent decline for Yangon from 362,050 ha last year to 354,414 ± 23,391 ha this year. On the other hand, Mon showed an 11 percent increase from 187,912 ha in 2021 to 207,684 ± 18,069 ha this year. Rakhine showed a more dramatic change in area from last year decreasing by 20 percent from 364,220 ha to 291,357 ± 11,946 ha. IFPRI yield estimates declined from 2.90 to 2.83 t/ha for Yangon, 2.99 to 2.54 t/ha for Mon, and 3.15 to 2.30 t/ha for Rakhine. This results in production declines of 4 percent (from 1,050 to 1,003 ± 66 thousand tons) in Yangon, 6 percent (562 to 528 ± 46 thousand tons) in Mon, and 42 percent (1,147 to 670 ± 27 thousand tons) in Rakhine.

The ADPC team found significant declines in cultivated rice area in the dry regions of Magway and Mandalay. Magway decreased by 28 percent from 265,059 ha last year to 191,018 ± 13,753 ha this year. The decline for Mandalay is lower but still significant, with a 21 percent decrease from 198,470 ha last year to 156,002 ± 9,360 ha this year. 2021's estimates were higher than GAD's reported areas in 2020 of 247,827 ha for Magway and 163,142 ha for Mandalay. The IFPRI yields for Magway decreased from 3.71 to 3.27 t/ha and for Mandalay from 3.58 to 3.31 t/ha. These changes led to an overall reduction in production of 36 percent in Magway this year, from 983 thousand tons to 625 ± 45 thousand tons, and a reduction of 27 percent in Mandalay, from 711thousand tons to 516 ± 31 thousand tons.

Shan also produced a significant amount of rice, accounting for nearly 11 percent of the total production in Burma last year. However, from 2022 compared to 2021, ADPC found a 9 percent decrease from 512,958 ha to 468,169 ± 59,926 ha in cultivated area. This result is closer to the number reported by GAD in 2020, which was 447,589 ha. IFPRI reported a slight decline in yield from 2.88 to 2.85 t/ha, resulting in an overall reduction in production from 1,477 thousand tons in 2021 to 1,334 ± 171 thousand tons in 2022, equivalent to a 10 percent decrease in production in Shan State.

Although last year's ADPC report did not include them, Kayah and Kayin's cultivated areas were estimated this year and found to be 22,532 ± 2,253 ha and 101,309 ± 8,003 ha, respectively. These findings are lower than the numbers reported in 2020 by GAD, which were 32,592 ha for Kayah and 167,907 ha for Kayin. The IFPRI yields declined this year from 2.51 to 2.20 t/ha in Kayah and from 3.12 to 2.79 t/ha for Kayin. This change resulted in a total production of 50 ± 5 thousand tons for Kayah and 283 ± 22 thousand tons for Kayin.

Overall, from the eleven regions it analyzed, ADPC found that Burma's total cultivated rice area declined by 7 percent from 4,775,976 ha in 2021 to 4,421,860 ± 311,955 ha in 2022. This finding is nearly 14 percent lower than the total cultivated area of 5,120,854 ha reported by GAD in 2020. IFPRI yields also decreased across the board, with the largest decrease in Rakhine and slight decreases in Ayeyarwady and Yangon, which produce significant amounts

of rice. This decrease has led to a 13 percent reduction in total production from 14,381 thousand tons last year to 12,567 ± 851 thousand tons this year.

1. INTRODUCTION

Rice cultivation in Burma is crucial for the country's economy, employment, and food security. While the economic situation has stabilized over the past months in Burma, the economic climate during the 2022 rice season has reportedly affected rice cultivation. Rice production in the 2022 monsoon season continued to face challenges caused by the political unrest and conflicts of the coup in February 2021.

The devaluation of Burma's currency, coupled with inflation, has increased costs associated with rice farming inputs, including seeds, fertilizers, and labor. Due to higher input costs, rice farming has become more arduous for farmers, diminishing their yields' profitability. In addition, the lack of access to resources, credit, and modern farming techniques limits the ability to achieve high rice yields. In 2022, there are more roadblocks and ongoing conflicts reported in many region and states of the country, especially in Magway, Mandalay, Rakhine, Sagaing (see Figure 1), which impact the transportation of food and other goods. The conflict has the potential to disrupt agricultural activities, including rice farming, and cause the displacement of farmers, the abandonment of their fields, and the reduction of cultivated areas.

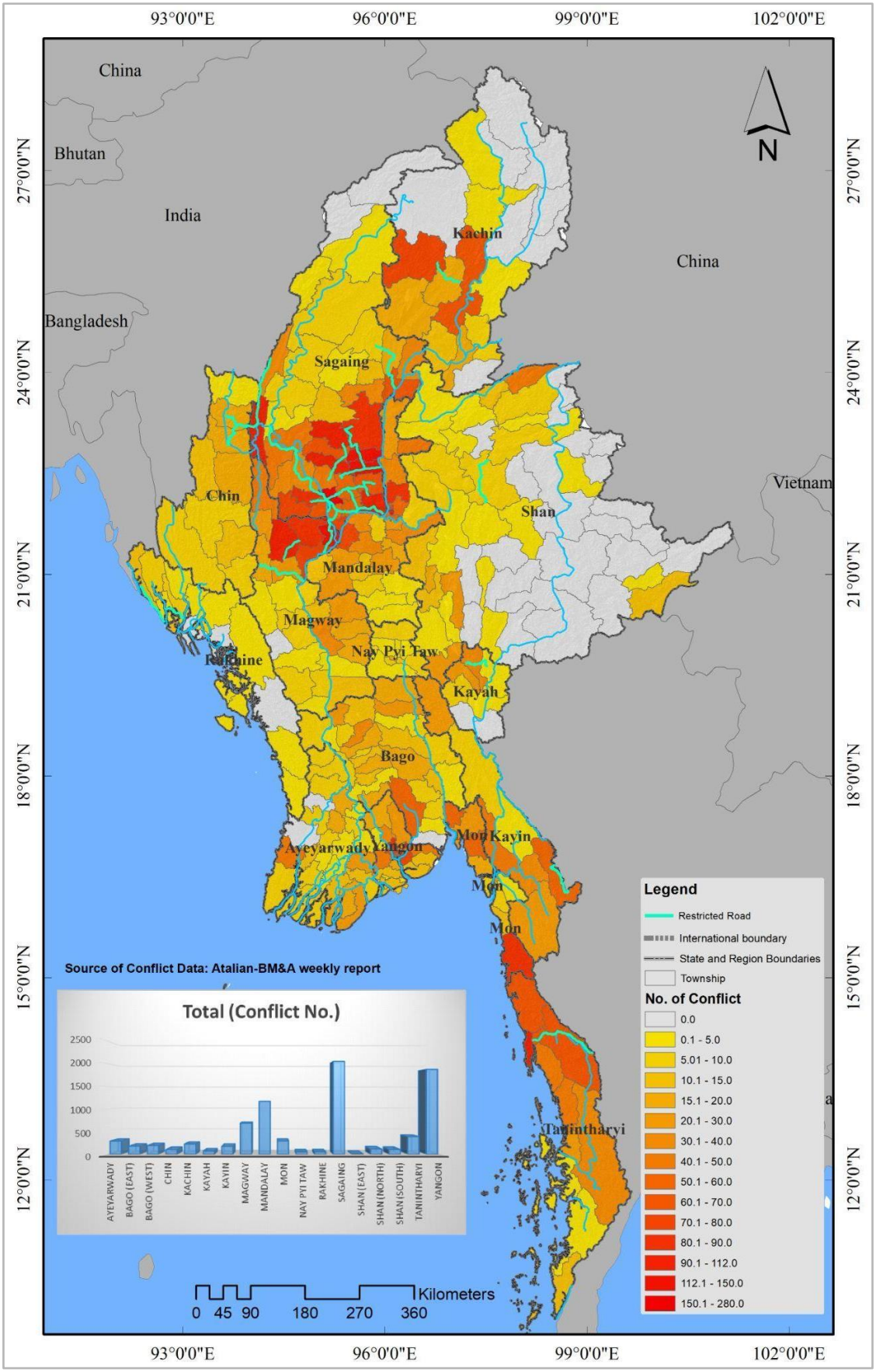


Figure 1. The number of violent incidents by township from January to December 2022 (Atalian-BM&A weekly report).

Another concern is the impact of natural disasters, including floods and droughts, with incidences of flooding and heavy rain reported for the coastal cities and townships in Yangon and Mon. In addition, the Sitrang typhoon in October may have impacted rice cultivation and growth in some coastal townships in Rakhine (Figure 2). As such, assessing the 2022 cultivated rice area for the major rice-producing regions in Burma is important. In this report, ADPC assesses the weather conditions and rice areas for Ayeyarwady, Bago, Kayah, Kayin, Magway, Mandalay, Mon, Rakhine, Sagaing, Shan, and Yangon for the 2022 monsoon rice crop season. The report uses satellite imagery, machine learning, and high-resolution data interpretation to provide area estimates with uncertainty levels. These data are then combined with yield estimates from IFPRI to estimate the total production with uncertainty levels.

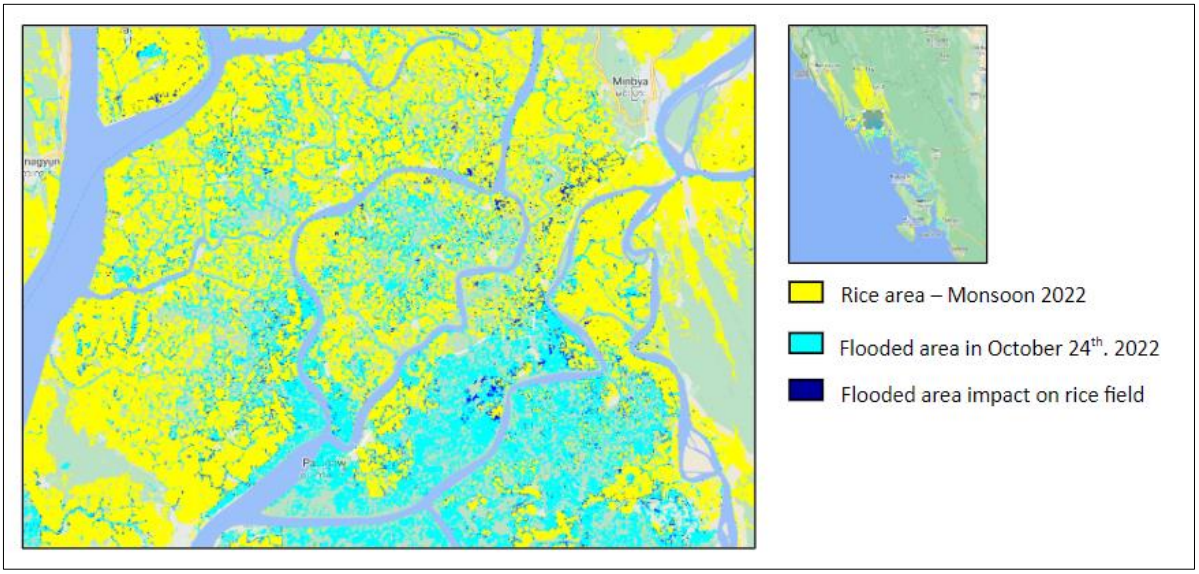


Figure 2. Flood mapping of flooding caused by the Sitrang storm in Pauktaw and Minbya townships in October 2022.

a) CLIMATE AND WATER RESOURCES

The cultivation of rice in Burma is heavily influenced by the monsoon season, which is a crucial period for rice growth due to its impact on water availability for the crop. Rice is a staple food for a large population in Burma, and adequate rainfall during the monsoon season is essential for the growth and development of rice plants. To fully understand the influence of rainfall patterns on rice cultivation, the team conducted an analysis using a comprehensive dataset ranging from 1981 to the present as a reference. The analysis focused on rainfall surpluses and deficits at the basin level, taking into account the catchment area's boundaries in determining overall water accessibility for rice cultivation.

Figure 1 shows the average rainfall over the full period in blue and the 2022 rainfall in red. The analysis revealed that there was more rainfall than average from January to April, less rainfall that average from May to September, and average rainfall conditions in October. However, rainfall patterns can have very specific spatial patterns.

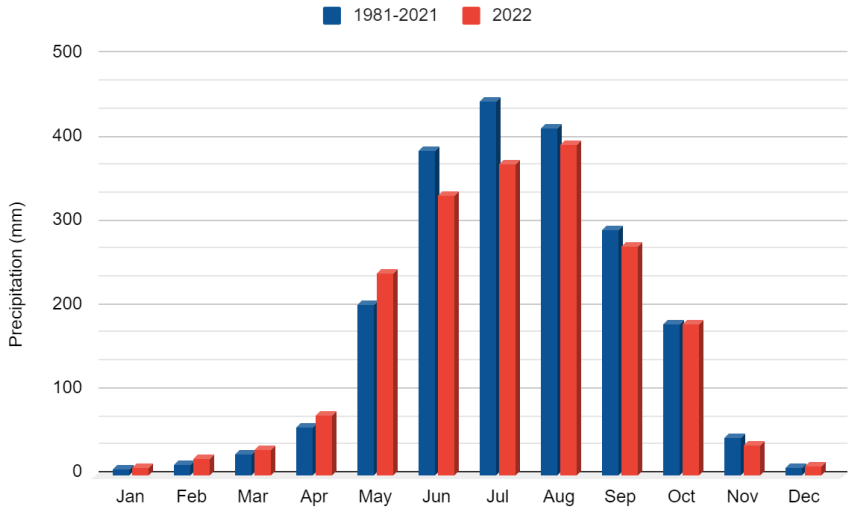


Figure 3. A comparison of the 2022 monsoon season's rainfall with the 1981–2021 averages.

The rainfall anomaly map in Figure 4 shows the difference in rainfall from the average over Burma and the relevant upstream areas. The map shows that the southern part of the country received higher precipitation, while the northern regions had below-average rainfall. Rakhine received much less rainfall than the rest of the country, resulting in a total deficit of 600 mm in Rakhine for the year.

The timing of rainfall is crucial for rice cultivation as it directly impacts the growth and development of the crop. Rice is a water-intensive crop and requires a consistent and adequate water supply to thrive. Too much or too little rainfall at critical stages of growth can result in reduced yields or complete crop failure. Figure 4 shows the monthly rainfall anomaly and cumulative anomaly for all states. For the coastal states of Ayeyarwady, Bago Mon, and Yangon, we see higher-than-average rainfall for May but a large rainfall deficit for June and a moderate rainfall deficit for July. However, because of higher-than-average precipitation in the following months, the total rainfall is similar to the average year.

Figure 5 shows a rainfall deficit in Magway for all but one month of the growing season, where rainfall conditions were good for Mandalay in May but below average in the months following. Sagaing shows plenty of rainfall for May and June but below-average rainfall in the three months following. Shan shows higher than average rainfall in two months, Kayan for three months, and Kayin for four months. However, total rainfall deficits over the year remain relatively low for most regions except Rakhine. Rakhine shows a rainfall deficit for all months of the year, resulting in a total deficit of 600 mm. Both rainfall amount and timing play an important role in rice cultivation. As such, the erratic rainfall for 2022, with low rainfall at the onset of the growing season and larger volumes during the growing season, can negatively affect rice yields in Burma.

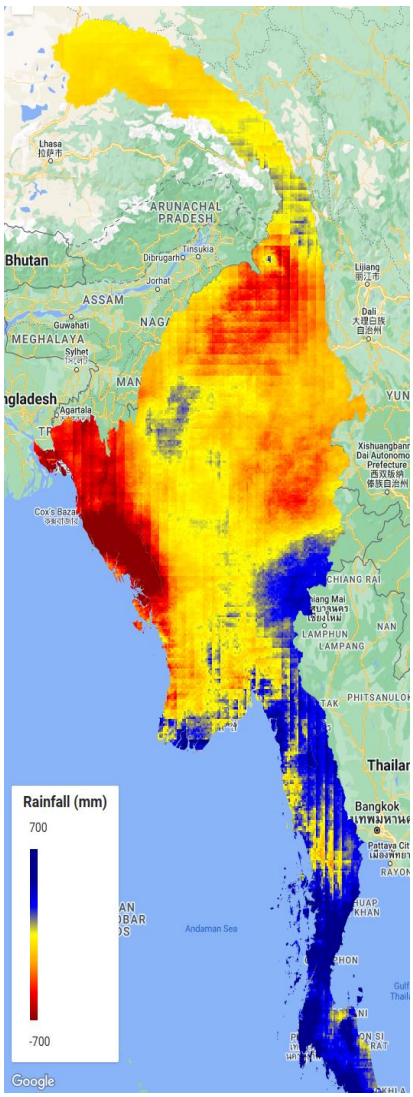


Figure 4. The Burma rainfall anomaly for 2022.

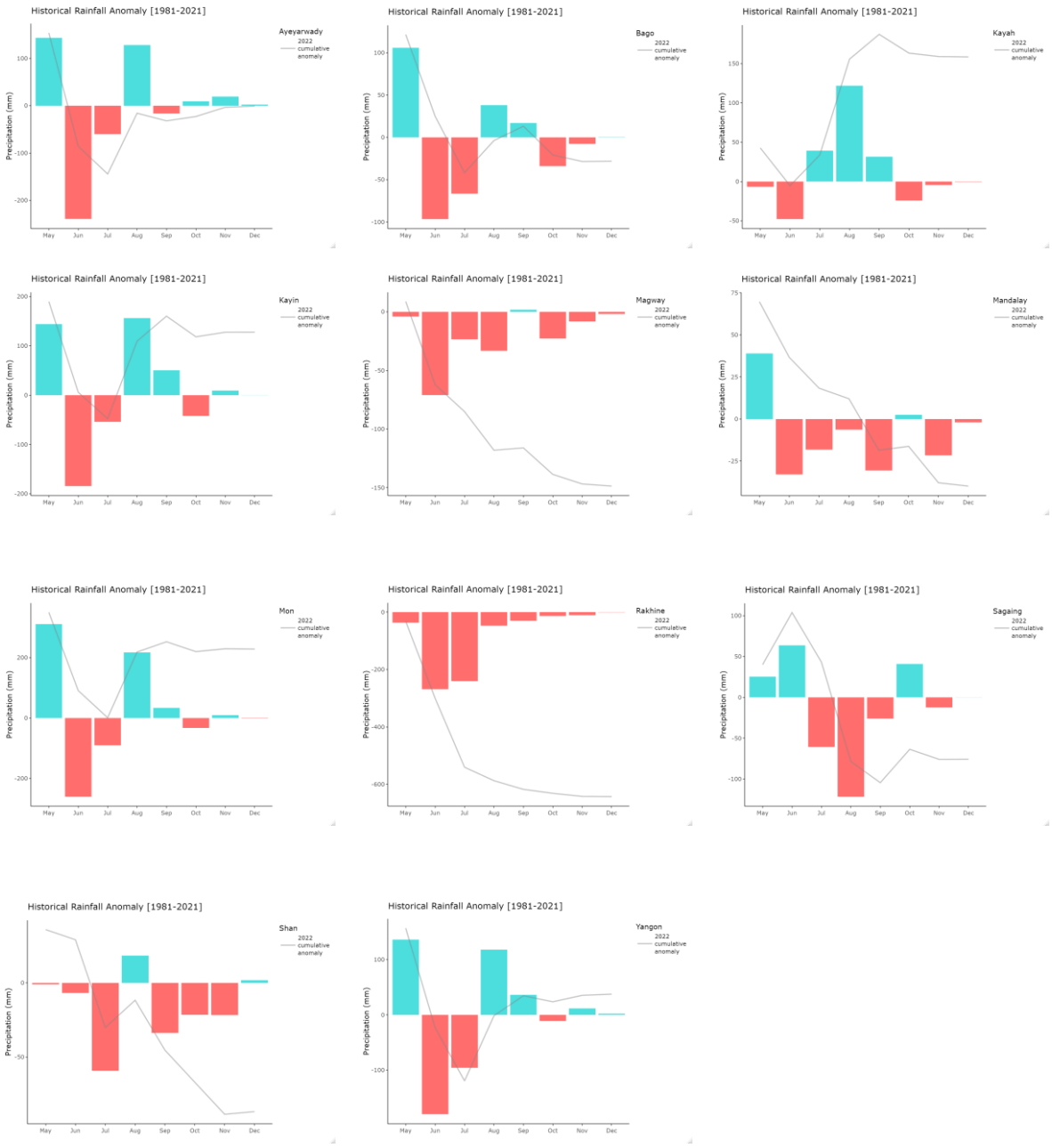


Figure 5. The cumulative rainfall anomaly for rice-producing states in Burma.

b) VEGETATION ANALYSIS

The Enhanced Vegetation Index (EVI), used to quantify vegetation greenness, often correlates well with rainfall data and is generally a good indicator of crop health. This study computed cumulative EVI anomalies for the predicted monsoon rice areas in 2021 and 2022. The cumulative EVI anomaly indicates the greenness of the vegetation in comparison to other years, which provides a proxy for vegetation health. Figure 6(A) shows that the rice fields, compared to a ten-year average, were greener in 2021 in all states but Magway, Mandalay, and Sagaing. On the other hand, Figure 6(B) shows this year having positive anomalies for all states, indicating much greener conditions despite the lower-than-average rainfall described in the climate analysis. The proceeding sections provide the cumulative EVI anomaly maps of the predicted rice areas after harvesting in October 2022 for each state.

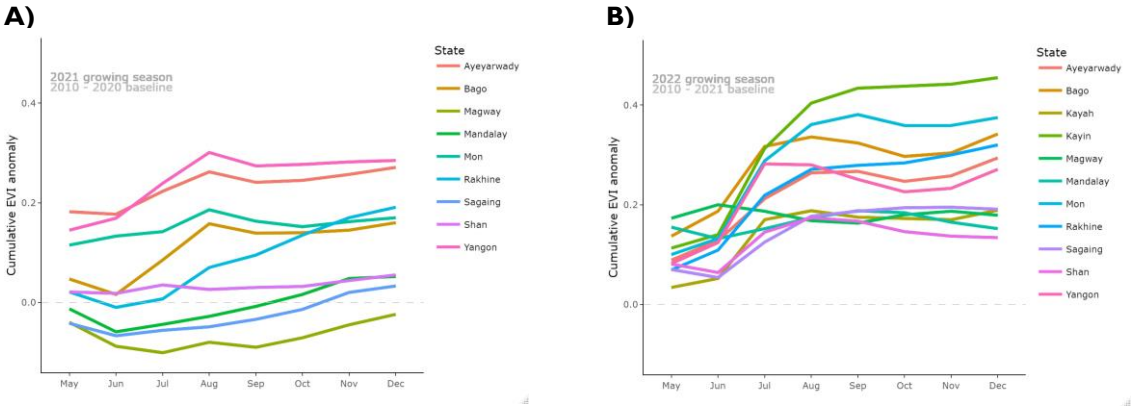


Figure 6. The cumulative EVI anomalies during the monsoon season for cultivated rice area in 2021 (A) and 2022 (B) for each state.

2. MONSOON RICE CULTIVATION AREA IN 2022

a) AYEYARWADY REGION

Ayeyarwady is located in the Ayeyarwady Delta in Burma's coastal zone. Figure 7(A) shows the rice, deepwater rice[2], and cropland distributions as calculated from satellite imagery for the monsoon 2022 season. Green areas represent cropland, while yellow and brown areas indicate monsoon rice and deepwater rice, respectively. Ayeyarwady grows more rice than any other state in Burma and accounts for 27.8 percent of the total monsoon rice area. All townships grew rice in 2022, and the breakdown by township in Figure 7(B) shows that Bogale and Labutta produced the most overall. Deepwater rice in 2022 is primarily seen in Kyaiklat, Maubin, Pyapon, Thabaung, and Yegyi.

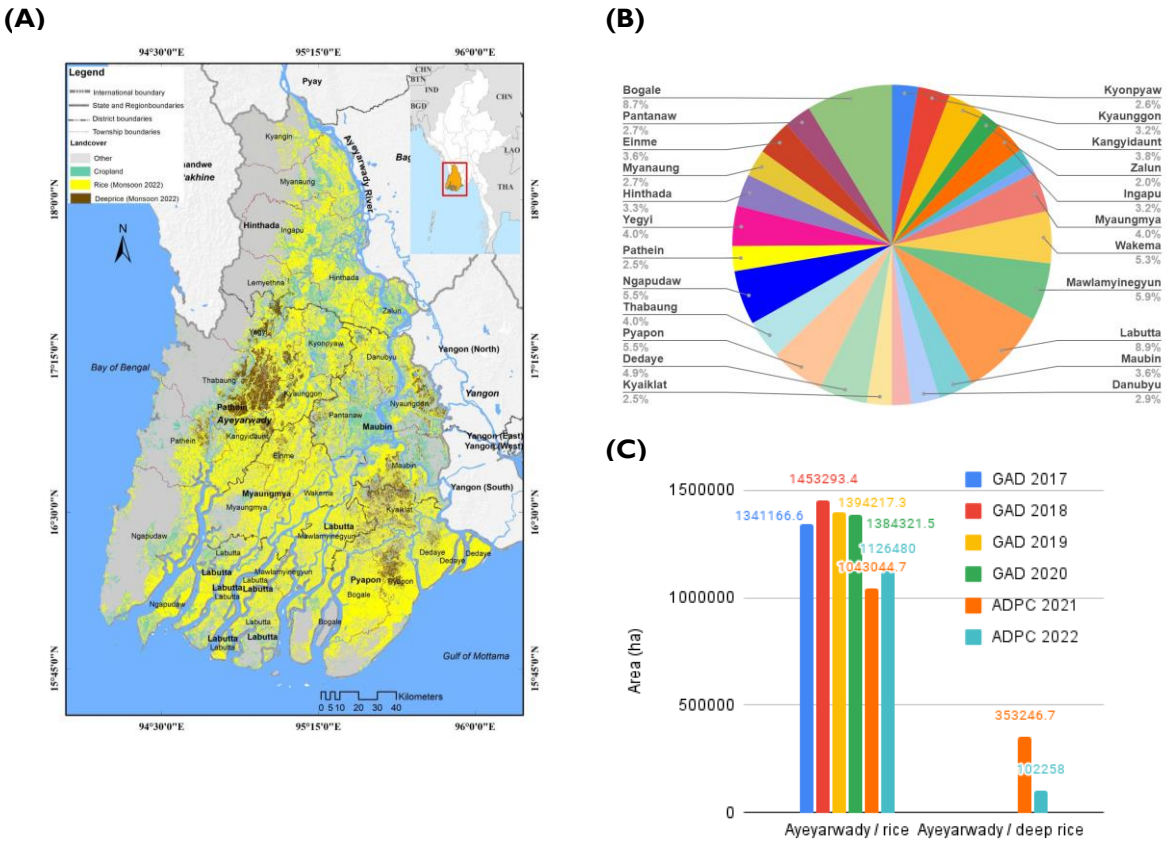


Figure 7. (A) The 2022 monsoon rice area in Ayeyarwady. (B) The rice area breakdown by township. (C) A state-level comparison of reported 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

The final 2022 monsoon area estimates after validation and error adjustment on a state level are 1,126,480 ha for rice with an uncertainty of 5.5 percent, and 102,258 ha for deepwater rice. This rice estimate is 8 percent higher than what ADPC reported last year. At the time

[2] Deepwater rice is rice that grows in flooded conditions (20 in deep) for at least a month.

of this report, rice area estimates have not yet been made available by the General Administration Department (GAD) or the Central Statistical Organization for 2021 and 2022. According to the ADPC estimates, there is 19 percent less rice area cultivation in 2022 than last reported by GAD in 2020. For reference, Figure 7(C) compares this study's estimates with available GAD data from 2017 to 2020. It should be noted that GAD does not distinguish between rice and deepwater rice in its reports, limiting the ability to compare values directly.

The fraction of rice area can be disaggregated by township and visualized spatially, as shown in Figure 8, where deeper colors signify townships with relatively larger areas of rice cultivation. Compared to last year, all townships remained the same except Maubin, Nyaungdon, Pantanaw and Pathein which are a shade lighter.

(A) 2021 **(B) 2022**

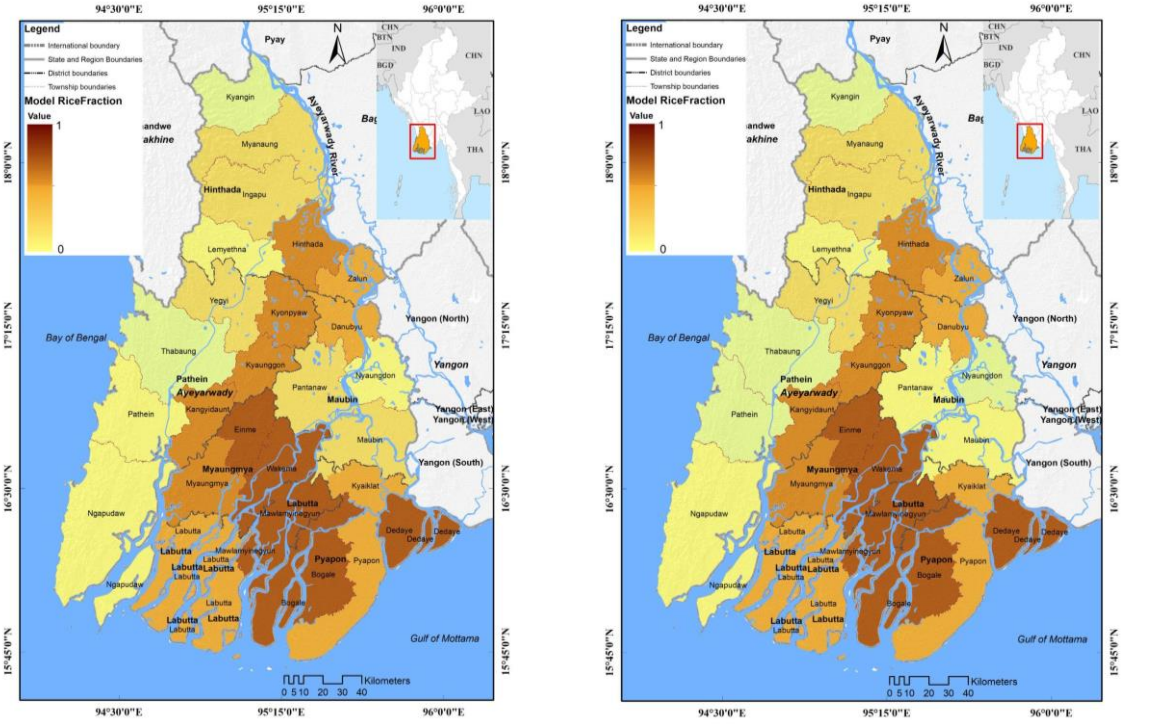


Figure 8. The rice fraction maps show the percentage of rice area planted relative to the total area by township for the monsoon seasons of 2021 (A) and 2022 (B).

The largest differences between 2021 and 2022 are in deepwater rice estimates, which are further visualized on a pixel level in Figure 9 Areas that remained the same since last year are yellow, while areas that experienced losses are red, and those that experienced gains are green.

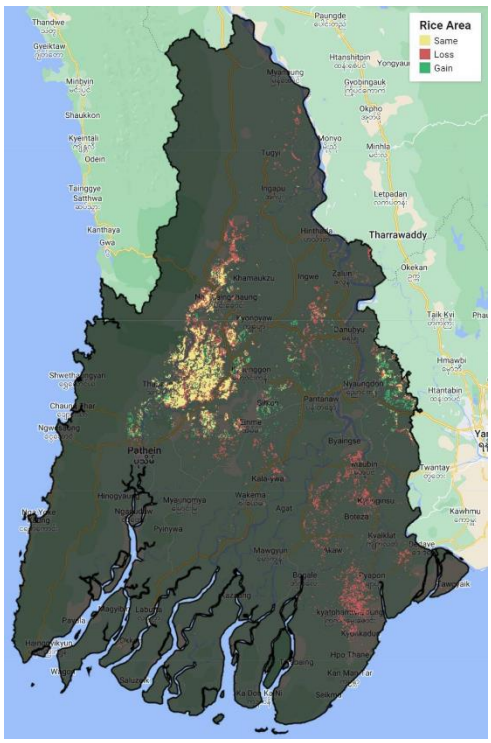
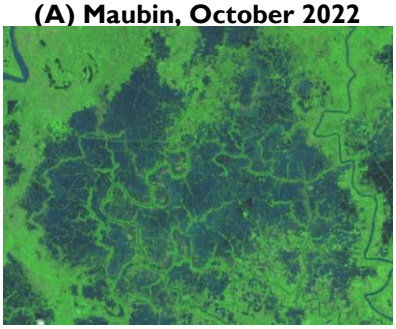


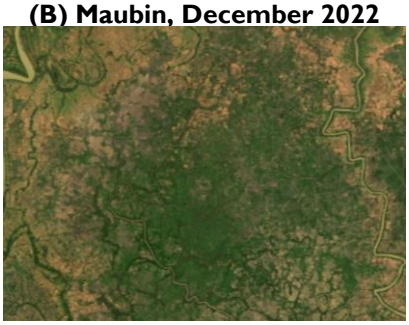
Figure 9. The change in rice area between 2021 and 2022. Yellow pixels signify no change in rice area, red areas indicate where there was growth in 2021 lost in 2022, and green represents where there was growth in 2022 gained over 2021.

Figure 10 shows examples of areas that were not fully cultivated in Maubin, Paynpon, and Bagole that contributed to the lower estimates of rice area this monsoon season.

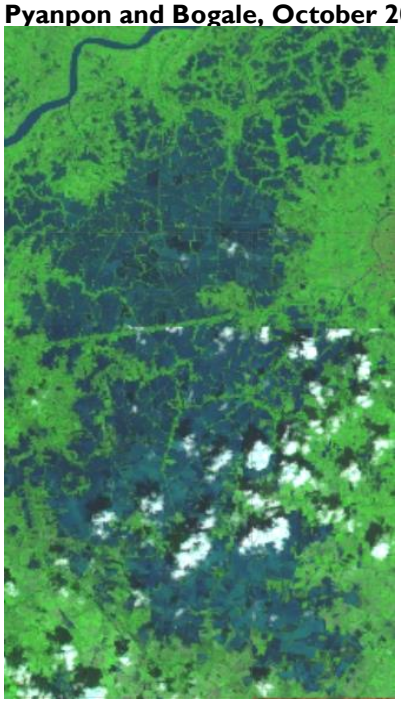
(A) Maubin, October 2022



(B) Maubin, December 2022



(C) Pyanpon and Bogale, October 2022



(D) Pyanpon and Bogale, December 2022

Figure 10. A comparison of rice planting areas in Maubin (upper images) and Pyanpon and Bogale (lower images) in Oct 2021 (left) and Dec 2022 (right). Sentinel-2 images (A) and (C) show the inundation area, and Planet images (B) and (D) show that deepwater rice is not fully cultivated in those areas.

Figure 11 compares the deepwater rice area estimates by township with the previous years' estimates and all townships exhibit significant reductions in area.

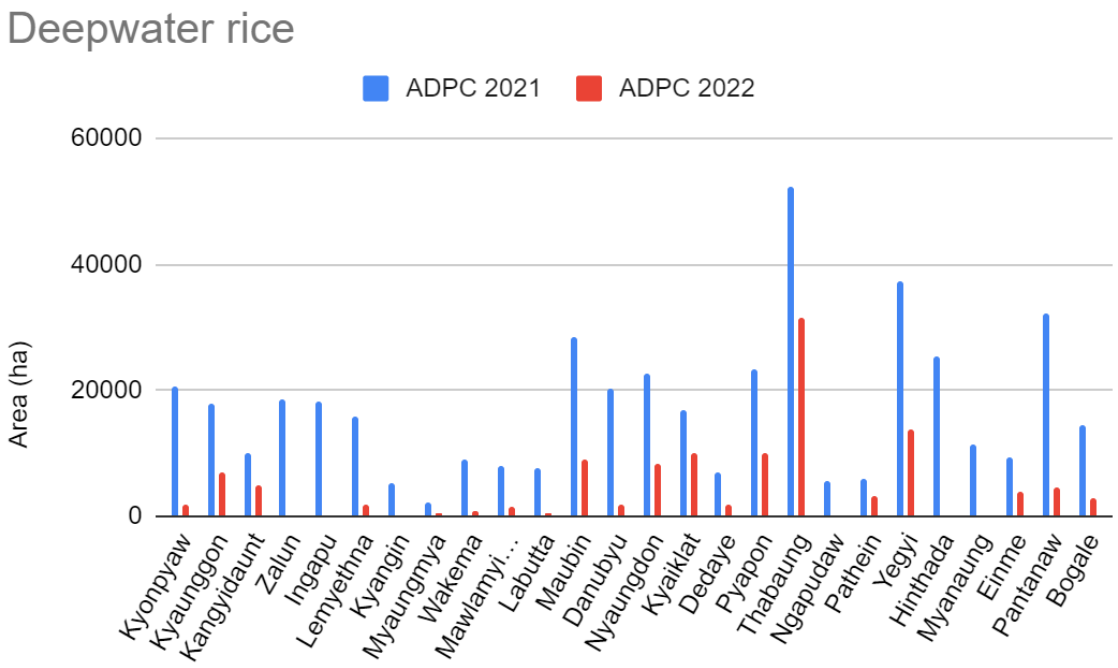


Figure 11. A comparison of Ayeyarwady rice area by township. The ADPC estimates for 2021 and 2022 are blue and red, respectively.

b) YANGON REGION

Yangon is located in the Ayeyarwady Delta in Burma's coastal zone. Figure 12(A) shows rice to be its most dominant crop, mostly concentrated in the southeastern and northwestern portions of the state and contributing 8 percent to the country's total rice cultivation this monsoon season. Figure 12(B) shows a pie chart breakdown of each township's percentage of total rice area. Thongwa and Kyauktan are the largest rice-growing townships, accounting for 14.9 percent each, followed by Kayan and Kungyangon.

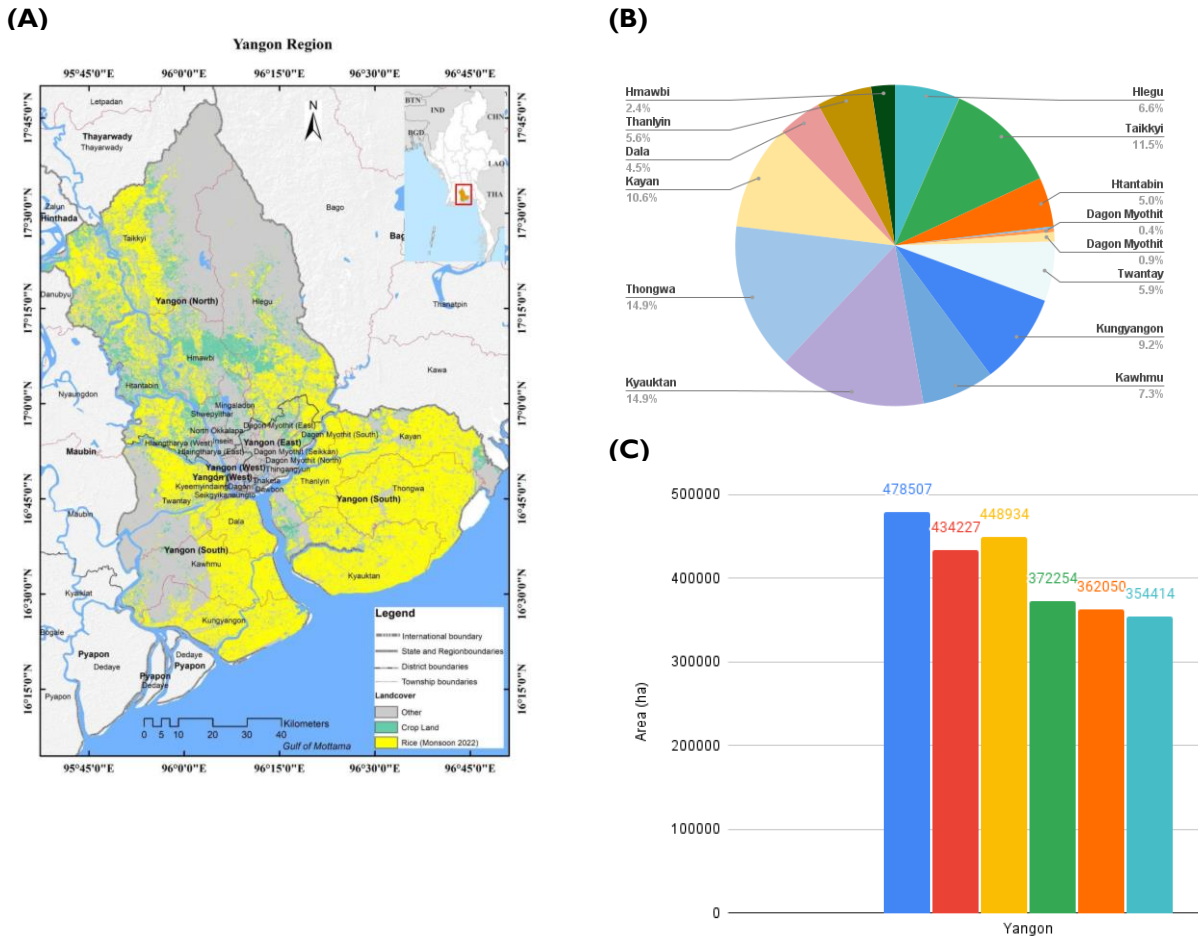


Figure 12. (A) The 2022 monsoon rice area in Yangon. (B) The rice area breakdown by township. (C)A state-level comparison of 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

The final error-adjusted rice area estimate for Yangon was calculated to be 354,414 ha with an uncertainty of 6.6 percent. This estimate is 2 percent less than last year's estimate and 4.8 percent less than GAD's in 2020. Figure 12(C) summarizes the monsoon season's annual state-level area estimates since 2017 shows a general decline in cultivated rice area.

Visualizing this information on a township-level is possible by overlaying the rice map with township boundaries. Figure 13 compares the rice area as a fraction of the total area by

township in 2021 and 2022. The fraction maps show that all townships have either maintained their shade or darkened, indicating higher rice fractions than last year.

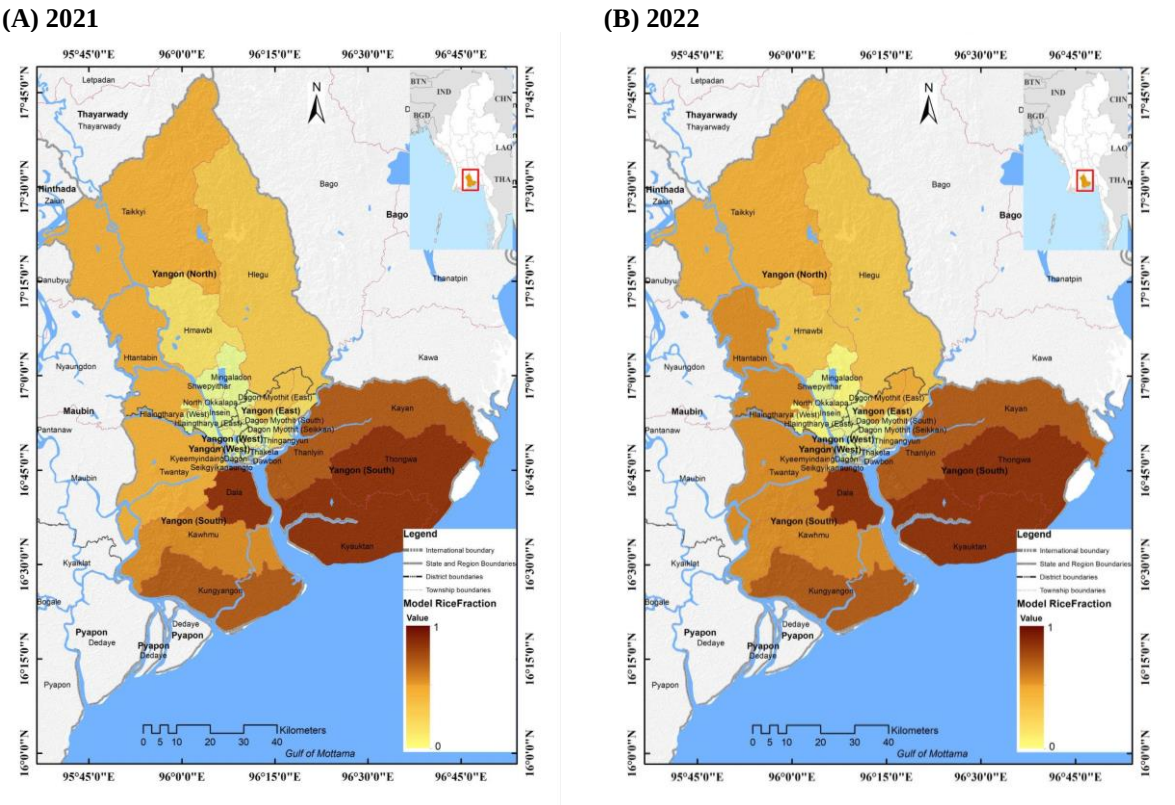


Figure 13. Rice fraction maps showing the percentage of rice area planted relative to the total area by township for monsoon season 2021 (A) and 2022 (B).

c) BAGO REGION

Bago is located in the country's coastal zone. Figure 14(A) shows large areas of rice cultivation extending through Bago East and West, accounting for 18.5 percent of the country's total cultivated rice in 2022's monsoon season. Figure 14(B) shows a breakdown of rice by township, where the highest percentages are found in Bago West townships Daik-U, Kawa, Kyauktaga, Thanatpin, and Waw. There are also relatively small areas of deepwater rice which grow almost entirely in Daik-U and Thanatpin.

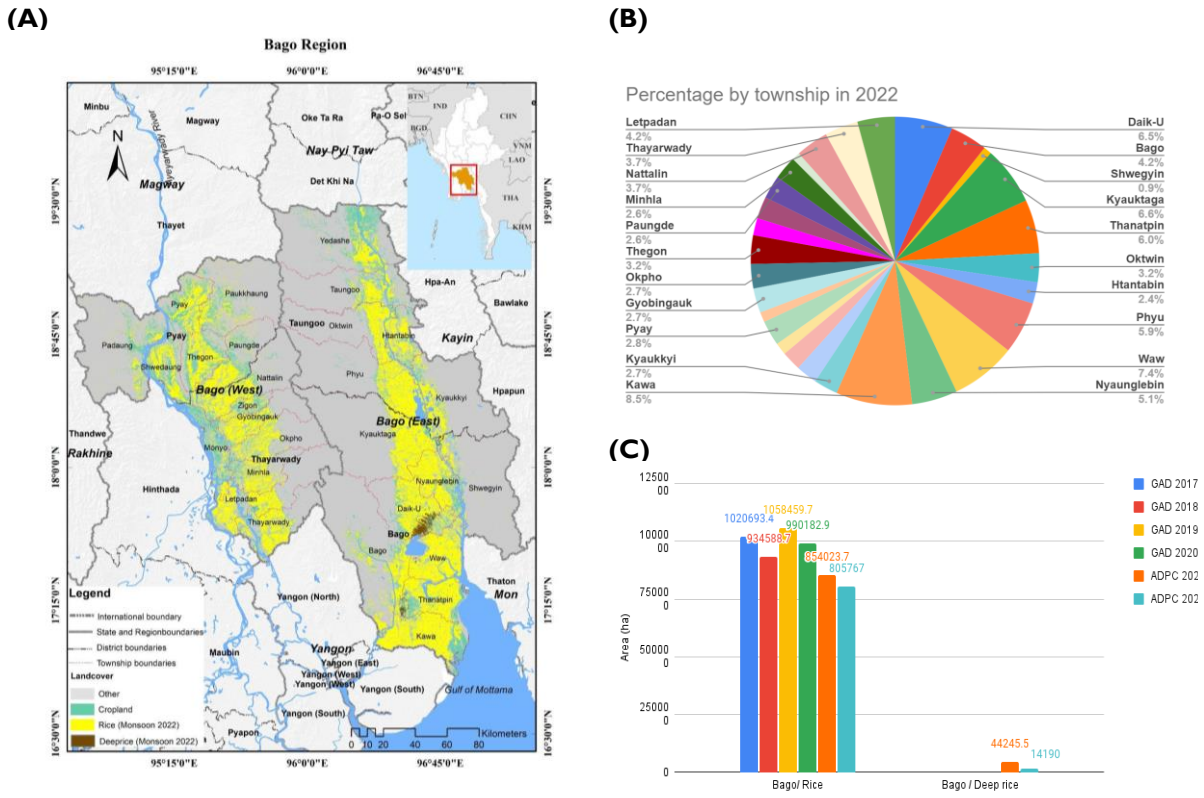


Figure 14. (A) The 2022 monsoon rice area in Bago. (B) The rice area breakdown by township. (C)A state-level comparison of reported 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment. .

The final area estimate on a regional level for Bago, after validation and error adjustment, is 805,767 ha for rice and 14,190 ha for deepwater rice, with uncertainties of 5.4 percent and 4.9 percent, respectively. This rice estimate is 6 percent lower than was reported last year and 18.6 percent less than GAD's in 2020. Figure 14 (C) summarizes the available monsoon rice area estimates for Bago since 2017 for comparison.

Rice fraction maps, as shown in Figure 15, help visualize these variations by township. The townships that are a shade darker this year are Minhla, Okpho, Paukkhaung, Phyu, and Zigon. This color change indicates an increase in rice-specific areas relative to the townships' areas. On the other hand, decreases are observed in Kyauktaga, Monyo, Nattalin, Oktwin, Pyay, and Yedashe.

(A) 2021

(B) 2022

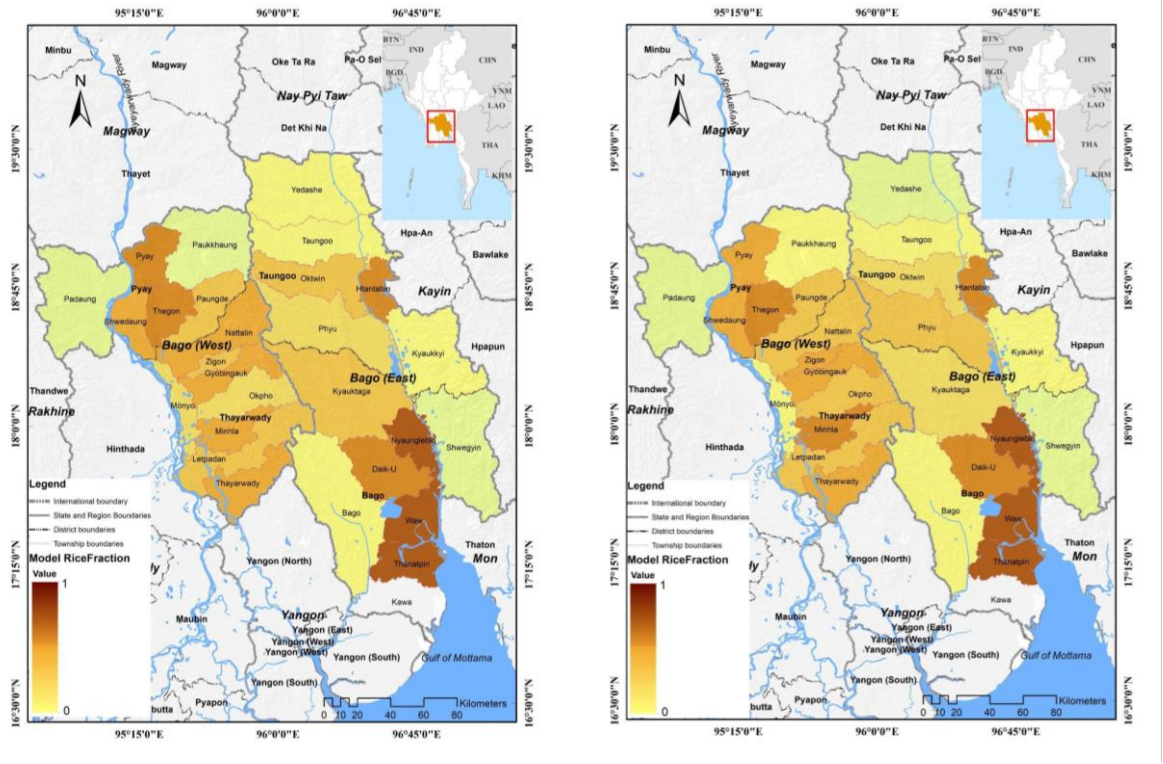


Figure 15. Rice fraction maps showing the percentage of rice area planted relative to the total area in each township for monsoon season 2021 (A) and 2022 (B).

d) MON STATE

Mon is located in the southeast along the Andaman Sea in Burma's coastal zone and accounts for 4.7 percent of the country's monsoon rice cultivation. Rice represents the majority of cropland area in Mon and is grown in all townships, particularly Chaungzon, Mudon, Paung, and Thaton, which make up two-thirds of the state's total monsoon rice area, see Figures 16(A) and 16(B).

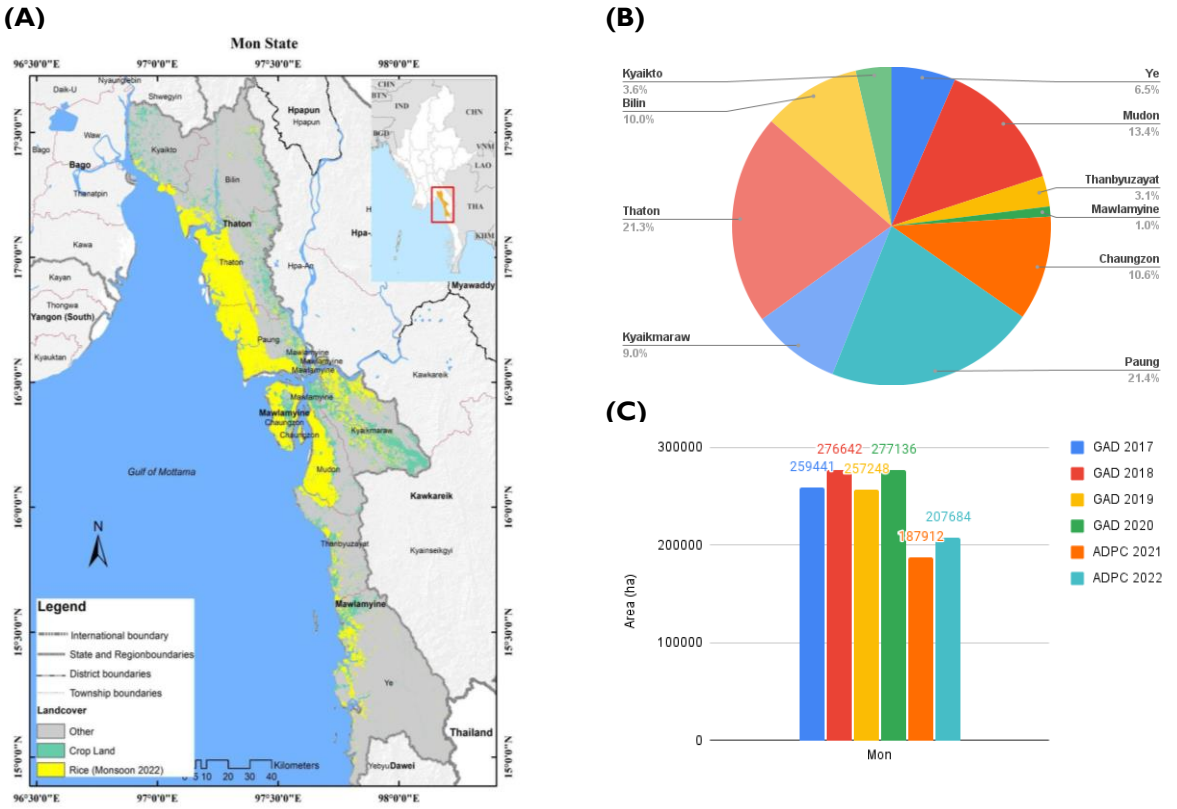


Figure 16. (A) The 2022 monsoon rice area in Mon. (B) The rice area breakdown by township. (C) A state-level comparison of reported 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

For the state of Mon, the total error-adjusted area was calculated to be 207,684 ha with an uncertainty of 8.7 percent. This area represents an increase of 11 percent compared to last year's estimates, although it is still 25 percent less than GAD's 2020 estimate. Figure 16(C) summarizes the monsoon season's state-level area estimates annually since 2017.

The rice fraction map in Figure 17 also shows Kyaikmaraw a shade darker than last year, indicating a higher fraction of total rice this year. Bilin is a shade darker as well, while all other townships remain the same.

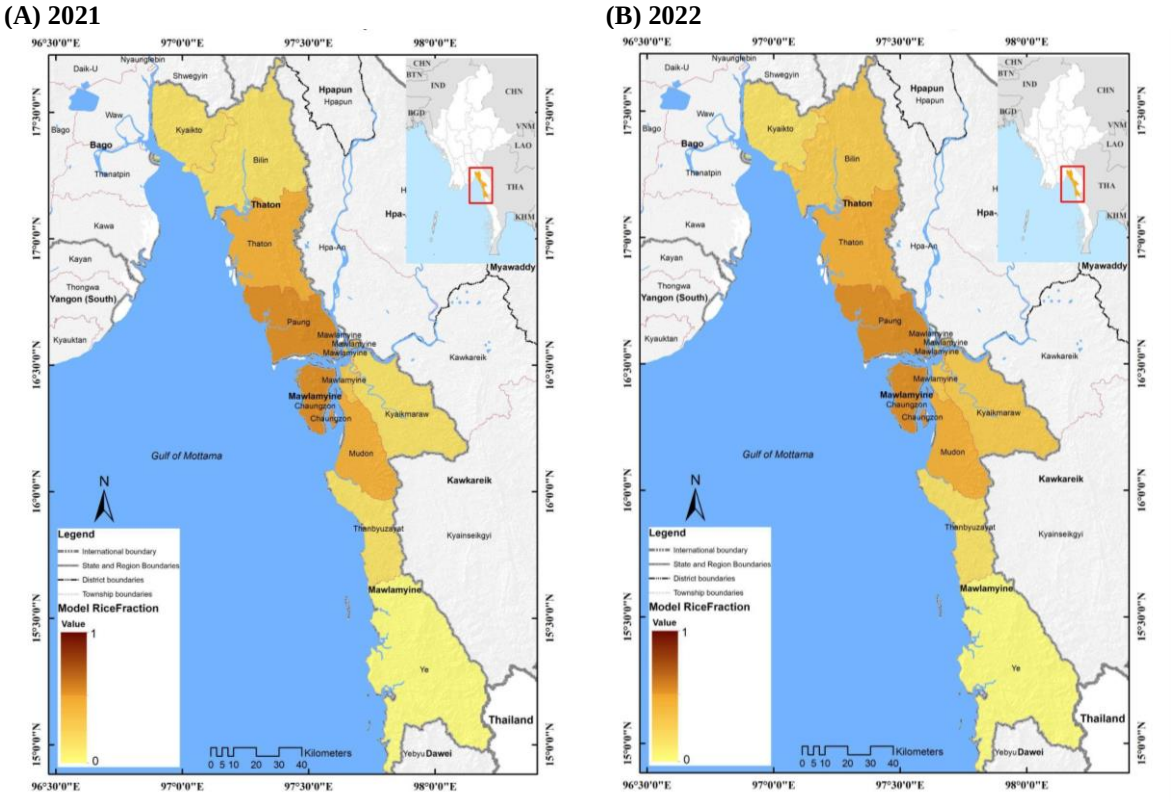


Figure 17. The percentage of rice area planted relative to the total area by township for monsoon season 2021 (A) and 2022 (B).

e) KAYIN STATE

Kayin is located in the southeastern coastal zone of Burma and contributed 2.3 percent of the country's total rice cultivation in the 2022 monsoon season. Figure 18(A) shows the distribution of rice and cropland across the region, and Figure 18(B) shows a breakdown of rice area by township. Hpa-An, Hlaingbwe, Kawkareik, and Kyainseikgyi comprise 90 percent of the cultivated rice area, with the remainder scattered across the state. ADPC did not estimate Kayin's rice area last monsoon season; therefore, no comparison is included.

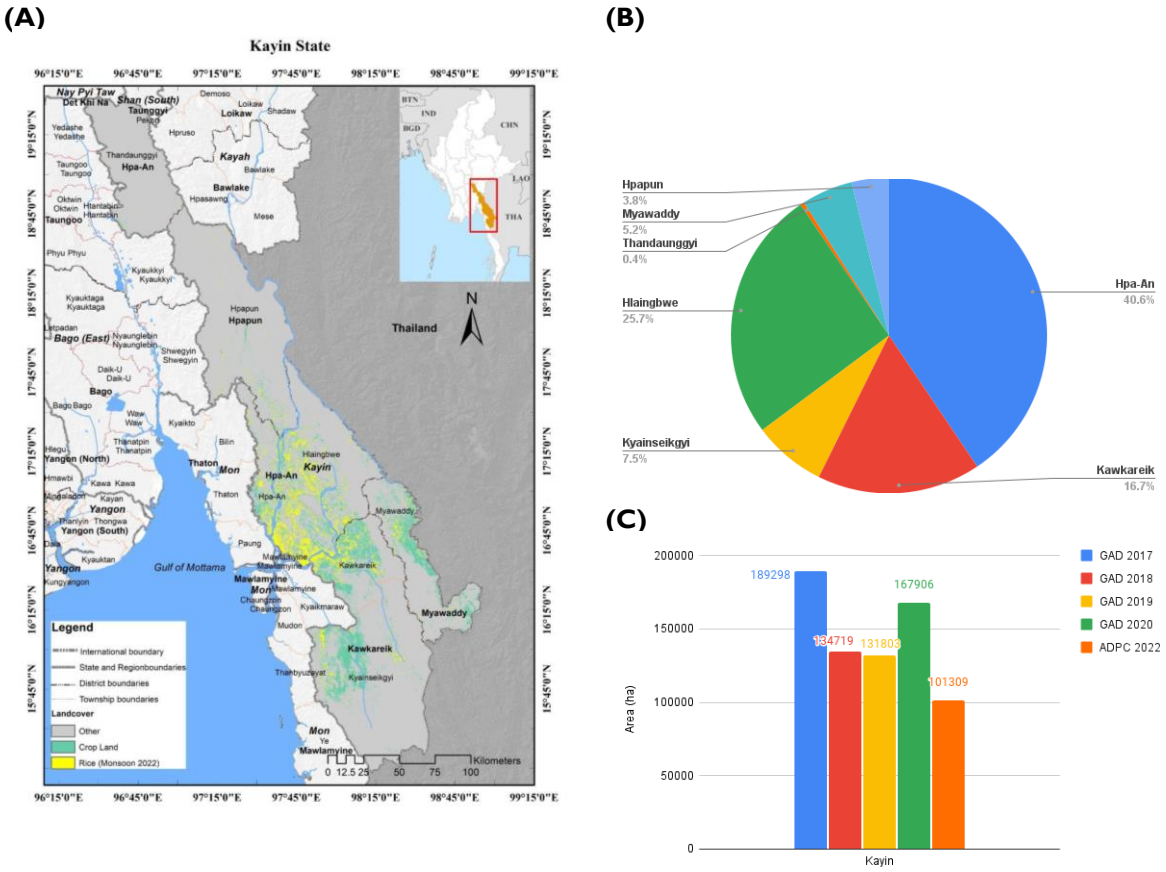


Figure 18. (A) The 2022 monsoon rice area in Kayin. (B) The rice area breakdown by township. (C) . A state-level comparison of reported 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment

The ADPC estimate after validating and error-adjusting the rice area on a state level is 101,309 ha with an uncertainty of 7.9 percent. This is 40 percent less area than GAD's estimate in 2020, and closer to GAD's 2018 and 2019 estimates. Figure 18 (C) summarizes available state-level estimates over recent years. ADPC did not estimate Kayin's rice area last monsoon season; therefore, no comparison is included.

The rice fraction map in Figure 19(A) indicates that all townships grew some rice, although Hpa-An grew the most by township area, followed by Hlaingbwe and Kawkareik.

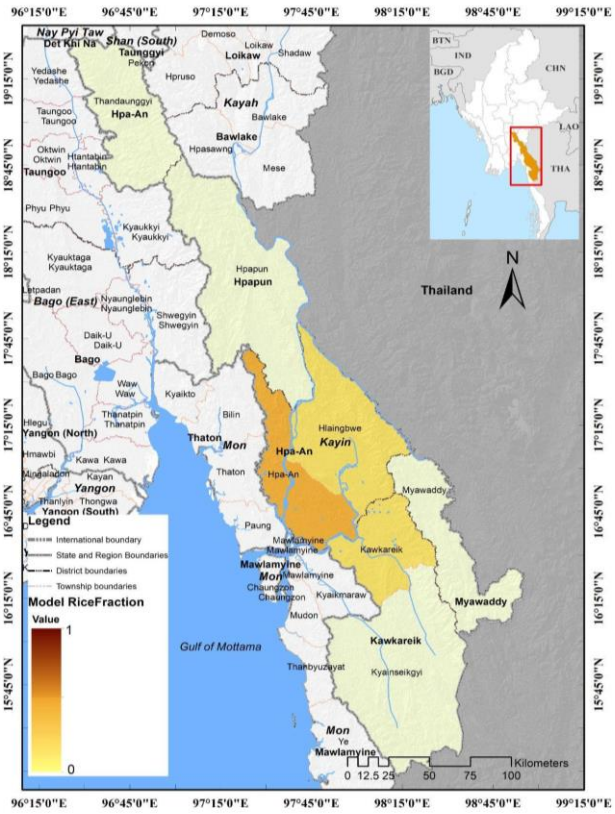


Figure 19. The percentage of rice area planted relative to the total area by township for the 2022 monsoon season.

f) RAKHINE STATE

Rakhine is located on the western coast along the Bay of Bengal in Burma's coastal zone. Its main monsoon crop is rice, which accounted for 6.6 percent of the country's total cultivated rice this season, concentrated mostly in the coastal regions (Figure 20[A]). Kyauktaw, Mrauk-U, and Pauktaw represent over a third of the state's cultivated rice area, with the remainder distributed throughout all the townships (Figure 20[B]).

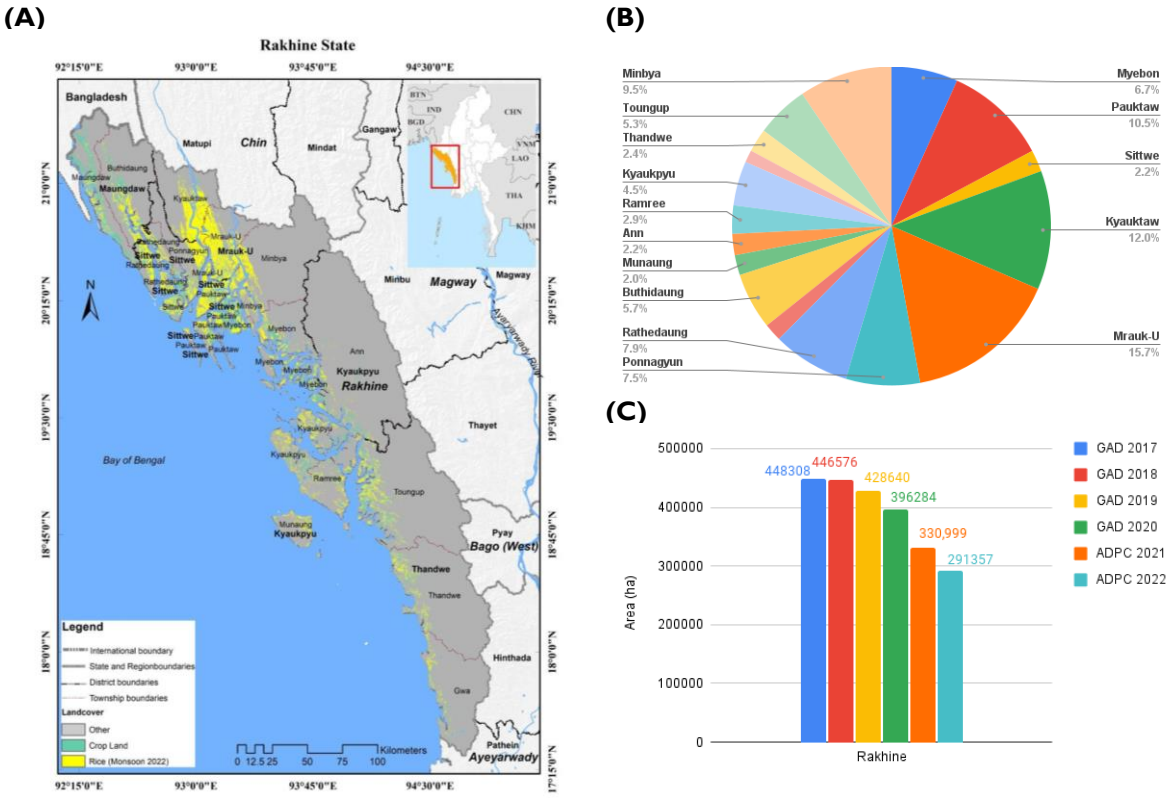


Figure 20. (A) The 2022 monsoon rice area in Rakhine. (B) The rice area breakdown by township. (C) A state-level comparison of reported 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

After validating and adjusting the rice area for errors, the estimate of rice area on a state level was 291,357 ha, with an uncertainty of 4.1 percent. This estimate is 20 percent less than last year's ADPC estimate and 26.5 percent less than the GAD estimate for 2020. Figure 20 (C) summarizes the rice area estimates for Rakhine's monsoon season since 2017, showing a steady decrease in area over the years.

As for the rice area in terms of relative township area, Figures 21(A) and 21(B) show the rice fraction by township in 2021 and 2022, respectively. It can be seen that while all townships remain the same, Kyaukpyu and Munaung are a shade lighter than last year, signifying relatively less rice area.

(A) 2021 **(B) 2022**

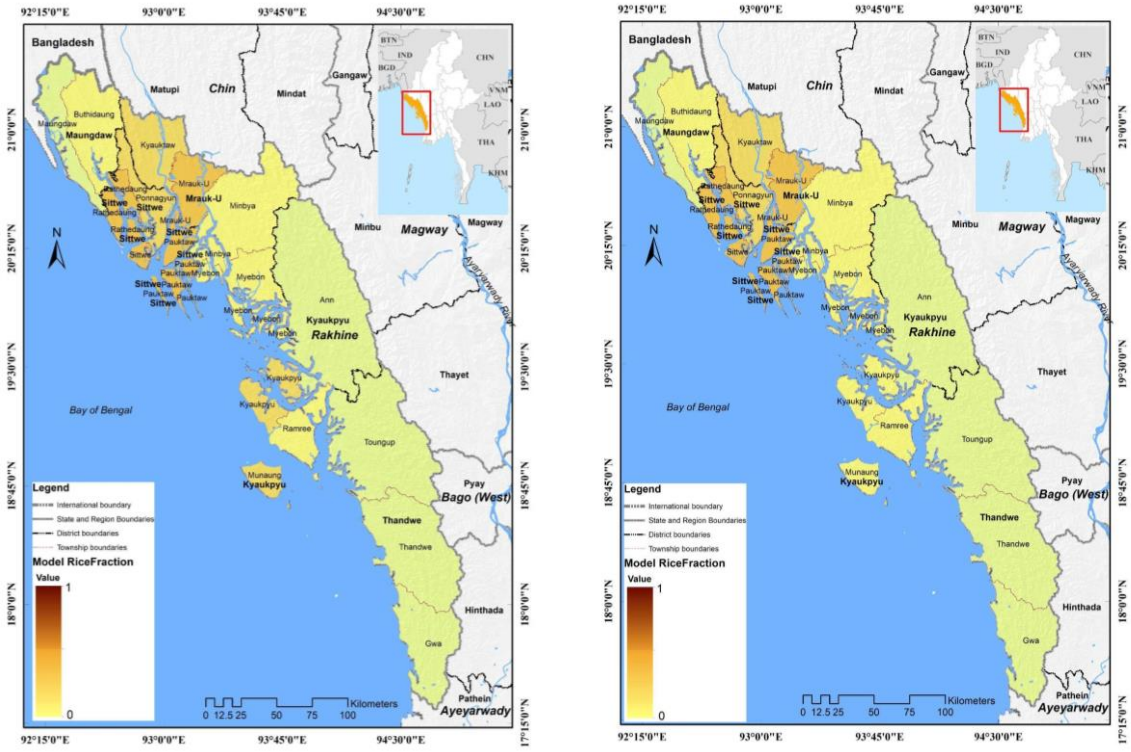


Figure 21. The percentage of rice area planted relative to the total area by township for the monsoon seasons in 2021 (A) and 2022 (B).

Figure 22 shows the pixel-level map of the change in rice area from 2021 to 2022. The townships show slight variations in area from 2021, but Toungup stands out with a visible loss in the south, as do Buthidaung, Pauktaw, and Rathedaung in the North.

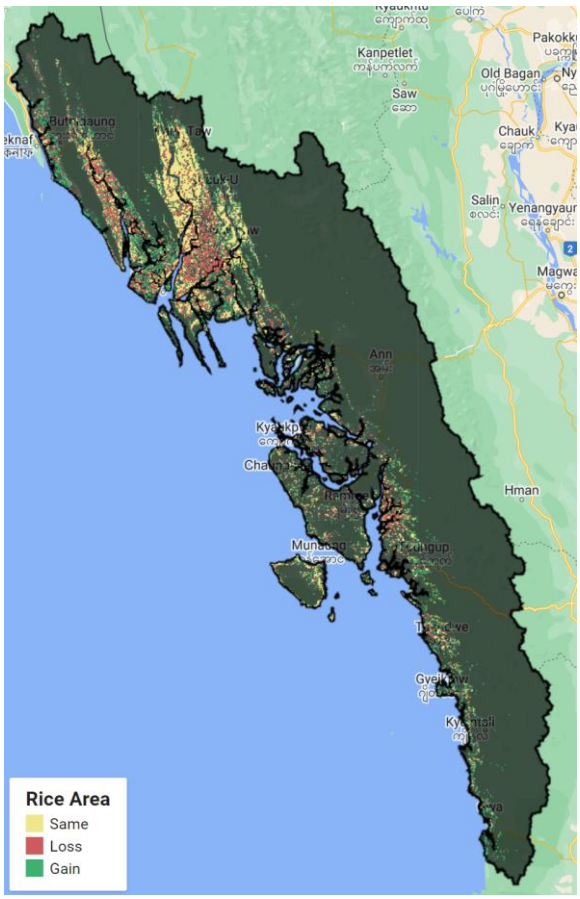


Figure 22. The change in rice area between the years 2021 and 2022. Yellow areas signify no change in rice area, red areas indicate where there was growth in 2021 lost in 2022, and green areas represent where there was growth in 2022 gained from 2021

Although these townships experienced a significant reduction in rice area, they are balanced by growth in other parts of the township. Figure 23 offers an alternative breakdown of the change in area by township. Besides the townships flagged in the rice fraction maps, the 2022 estimates were generally higher than 2021's. Compared with a four-year historical average of available GAD data from 2017 to 2020, all townships show a reduction in cultivated rice area in 2021 and 2022 except Munaung and Kyaukpyu, which showed slightly higher estimates in 2021. Gwa and Maungdaw are significantly lower in ADPC's estimates than in GAD's over the years.

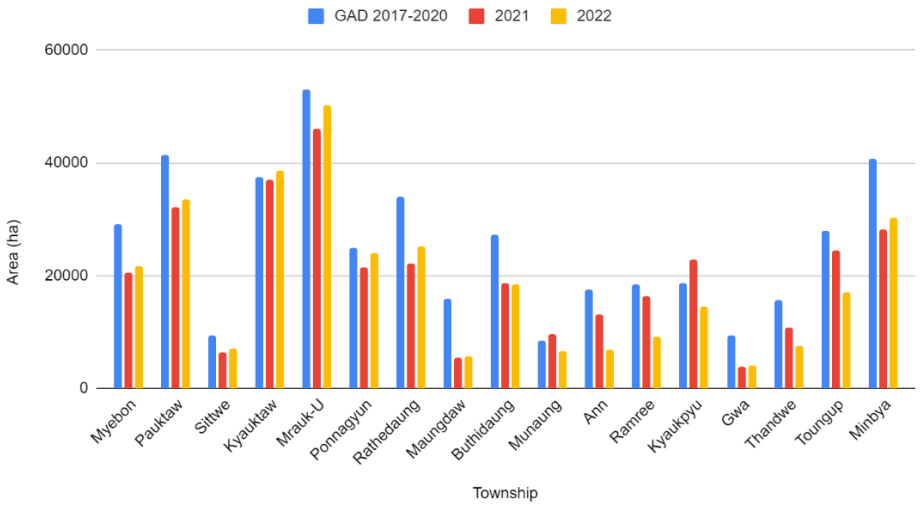


Figure 23. A comparison of Rakhine rice area by township. The GAD average for 2017–2020 is blue, and ADPC estimates for 2021 and 2022 are red and yellow, respectively.

e) MANDALAY REGION

Mandalay is located along the east bank of the Ayeyarwady River in the country's central dry zone. It contributed 3.5 percent of the country's total monsoon rice area in 2022, mostly from the central and south-central townships (Figure 24[A]). Madaya, Myittha, and Wundwin account for over a third of the state's cultivated rice area; Kyaukse, Pyawbwe, Thazi, and Yamethin account for another third; and the remainder is disbursed in the townships per the breakdown in Figure 24(B).

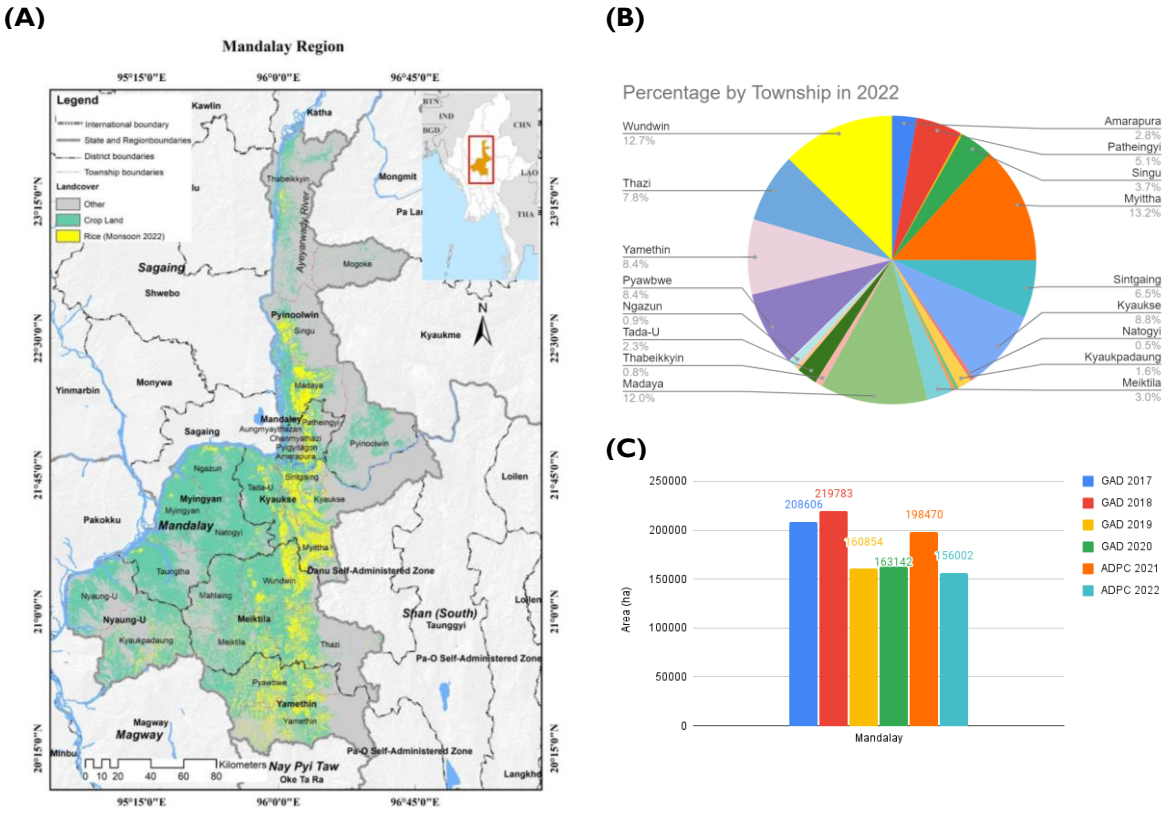


Figure 24. (A) The 2022 monsoon rice area in Mandalay. (B) The rice area breakdown by township. (C) A state-level comparison of 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

Validation and error adjustment of the area estimates are performed on a state level. ADPC's final area estimate for Mandalay in 2022 was 156,002 ha with an uncertainty of 6 percent, which is 21 percent lower than ADPC's estimate for monsoon 2021 and 4 percent lower than the GAD estimates for 2020. Figure 24 (C) summarizes the rice area estimates for Mandalay annually since 2017 for reference.

Figure 25 visualizes this variability in rice area by township relative to the township's total area. The rice fraction maps show SingU, Madaya, Sintgaing, Kyaukse, Myittha and Yamethin as a shade lightly darker this year, indicating a relative increase in their rice areas from last year. Kyaukpadaung is a shade lighter, indicating a reduction in rice area this year.

(A) 2021 **(B) 2022**

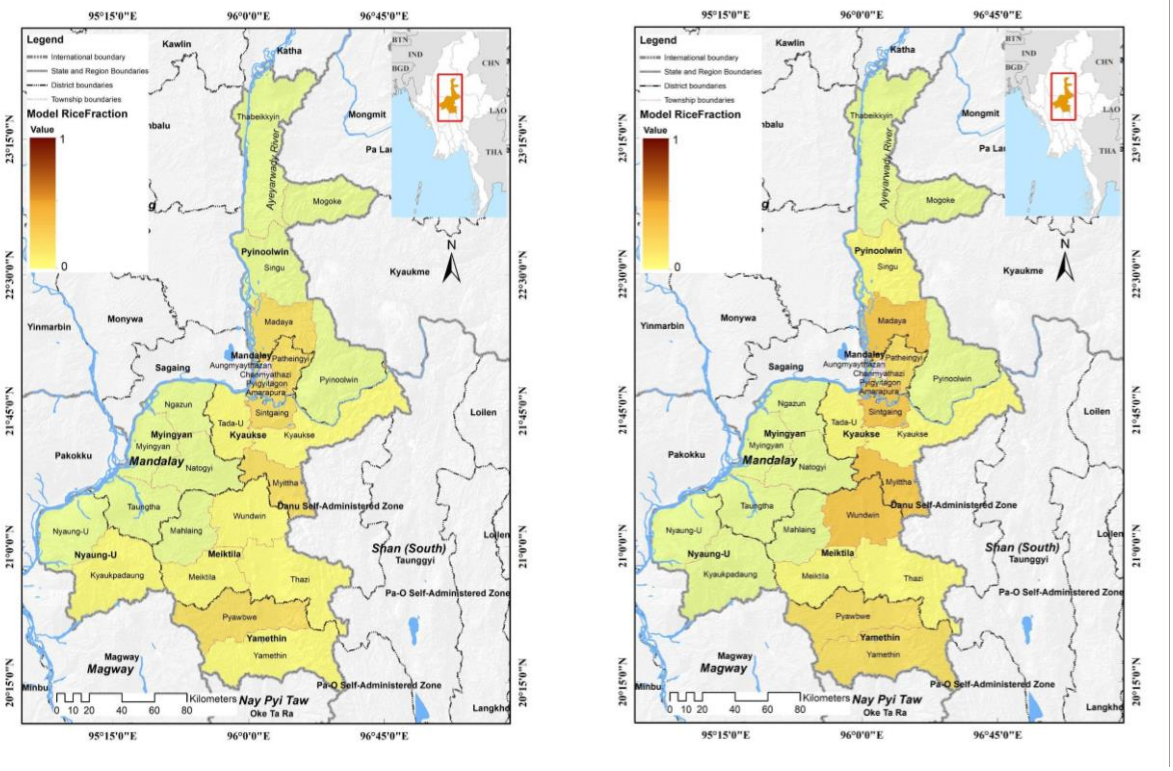


Figure 25. The percentage of rice area planted relative to the total area by township for the monsoon seasons in 2021 (A) and 2022 (B).

Figure 26(A) visualizes the absolute differences on a pixel level, showing the areas of change since last year. While much remained the same, Myittha and Yamethin stand out with increased rice cultivation in 2022, and Pyawbwe and Meiktila with decreased cultivation.

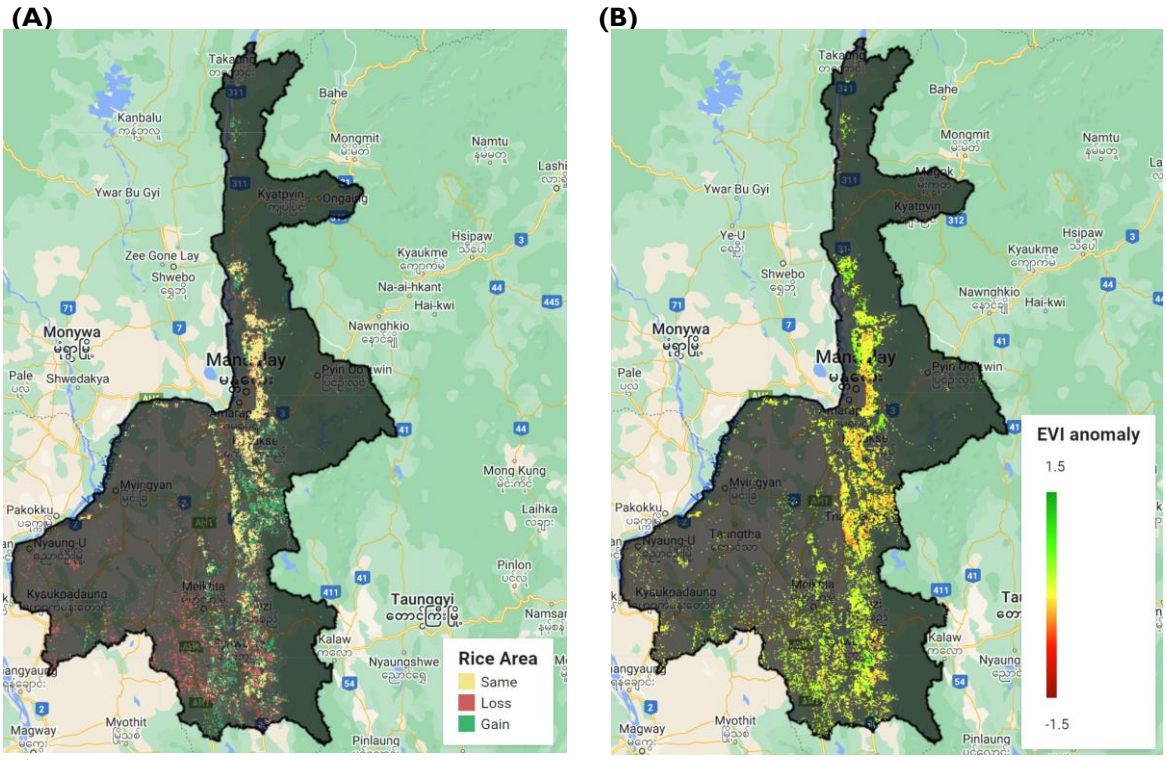


Figure 26. (A) The change in rice area between the years 2021 and 2022. Yellow areas signify no change in rice area, red areas indicate where there was growth in 2021 lost in 2022, and green represents where there was growth in 2022 gained from 2021 (B). The 2022 cumulative EVI anomaly of areas in (A).

Figure 27 compares ADPC's 2021 and 2022 estimates with an historical average of available GAD data from 2017 to 2020 by township. In general, ADPC's 2022 estimates are similar to the GAD's estimates from previous years, while the 2021 ADPC estimates were higher. Kyaukse, Myittha, and Wundwin show significant increases in rice area compared to last year, however most townships in the Meiktila, Myingyan, Nyaung-U, and Yamethi districts show a significant reduction in area.

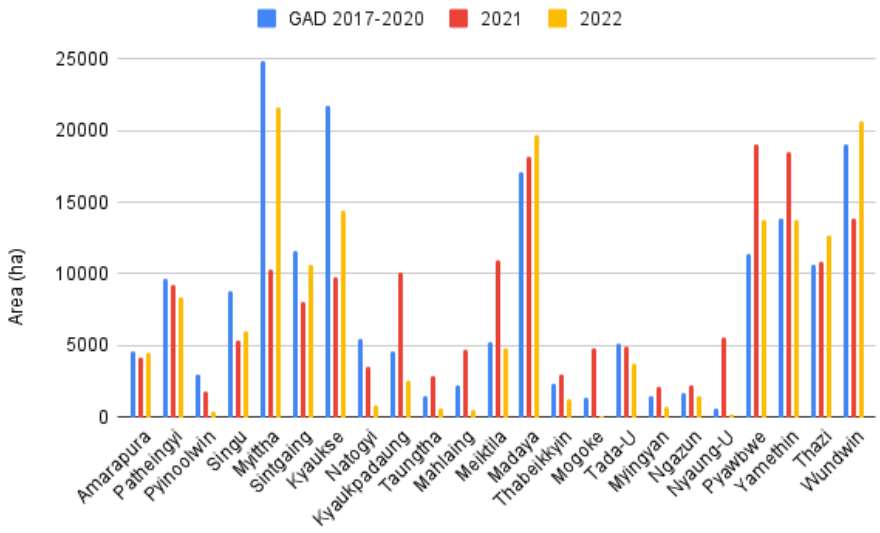


Figure 27. A comparison of Mandalay rice area by township. The GAD average for 2017–2020 is blue, and ADPC estimates for 2021 and 2022 are red and yellow, respectively.

f) MAGWAY REGION

Magway is located in Burma's central dry zone and accounted for 4.3 percent of the country's total monsoon rice area in 2022. Most of the cultivated rice is concentrated in townships along the Ayeyarwady river (Figure 28[A]), with Minbo, Pwintbyu, and Salin containing nearly half of the state's total rice area (Figure 28[B]).

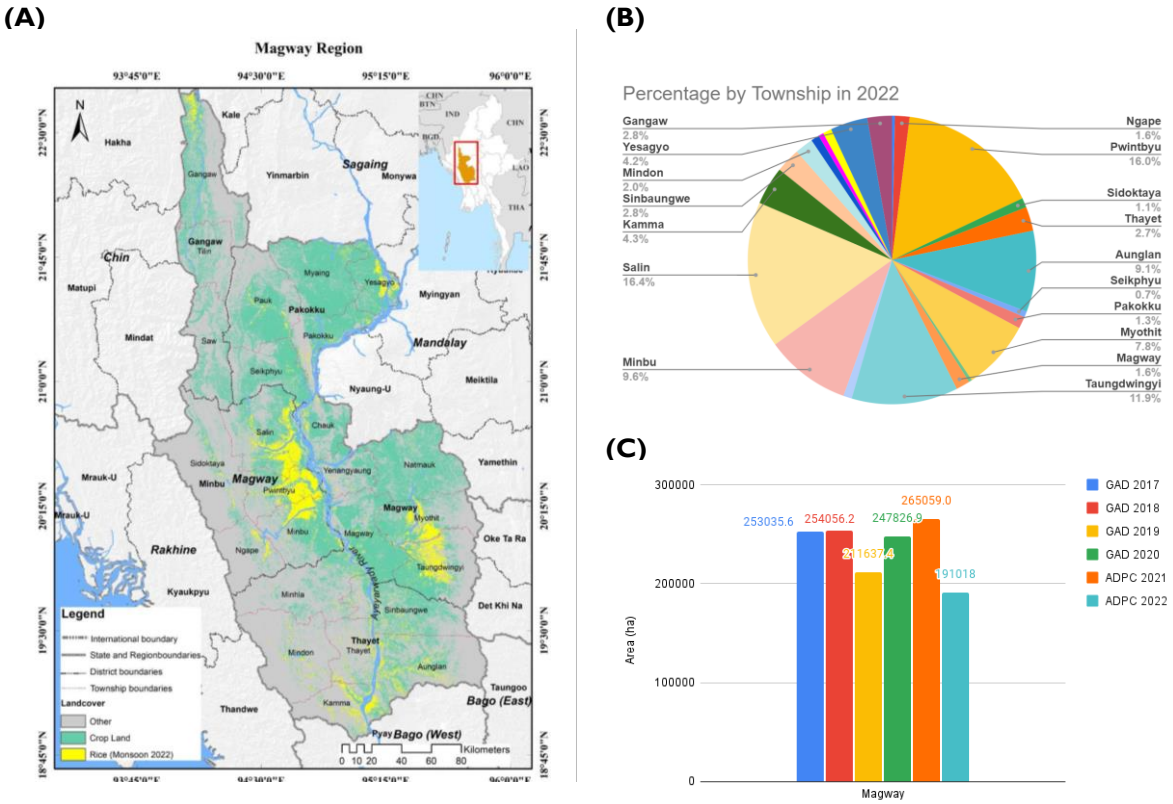


Figure 28. (A) The 2022 monsoon rice area in Magway. (B) The rice area breakdown by township. (C) A state-level comparison of 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error

Although the area estimates on a pixel level can be computed per township, the validation and error-adjusting scheme is representative only at the regional level. Magway's final rice area estimate for monsoon 2022 was 191,018 ha with an uncertainty of 7.2 percent. This estimate is 28 percent lower than last year's ADPC estimate and 23 percent less than GAD's in 2020. Figure 28(C) summarizes the available regional level estimates over recent years.

In terms of cultivation area change relative to township area, the rice fraction maps in Figures 29(A) and 29(B) show Gangaw, Minbu, Myothit, and Taungdwingyi a shade lighter than last year, indicating a decrease in relative rice area.

(A) 2021 **(B) 2022**

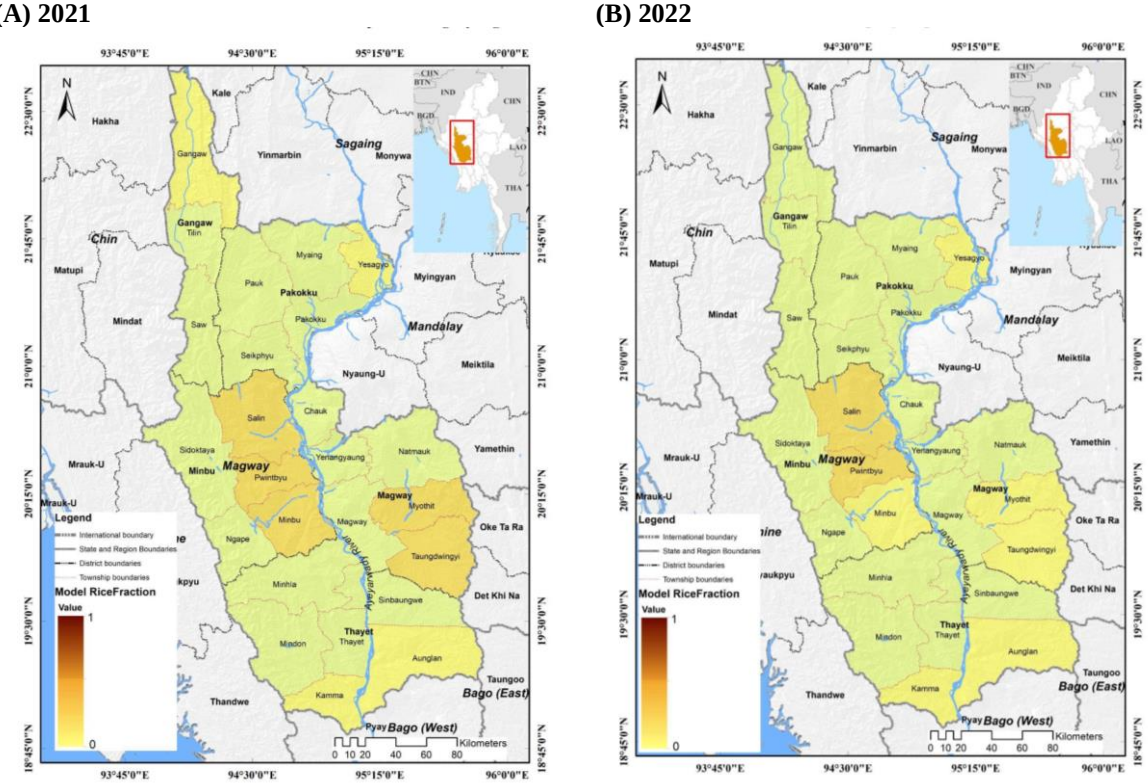


Figure 29. The percentage of rice area planted relative to the total area by township for the monsoon season of 2021 (A) and 2022 (B).

Figure 30(A) maps the change in rice area on a pixel level and shows that southern states exhibit a gain in area and northern states, although sporadic, exhibit a loss in area.

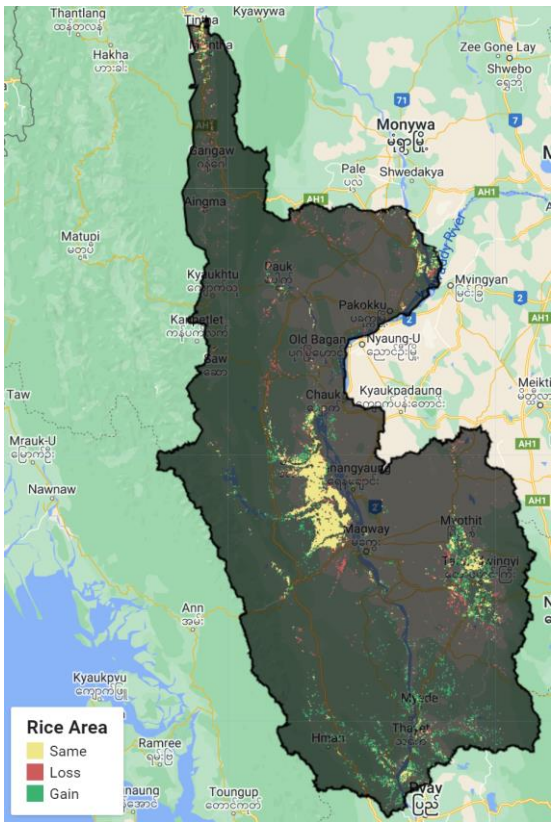


Figure 30. The change in rice area between 2021 and 2022. Yellow areas signify no change in rice area, red areas indicate where there was growth in 2021 lost in 2022, and green areas show where there was growth in 2022 gained from 2021.

Figure 31 compares the ADPC estimates from 2021 and 2022 by township to a historical average of available GAD data from 2017 to 2020. Minbu, Magway, Pwintbyu, Salin, and Yesagyo all show an increase in area over the years, while Gangaw, Minhla, Myaing, and Seikphyu show decreases. It can be observed that Natmauk, Saw, and Tilin more or less stopped growing rice this year.

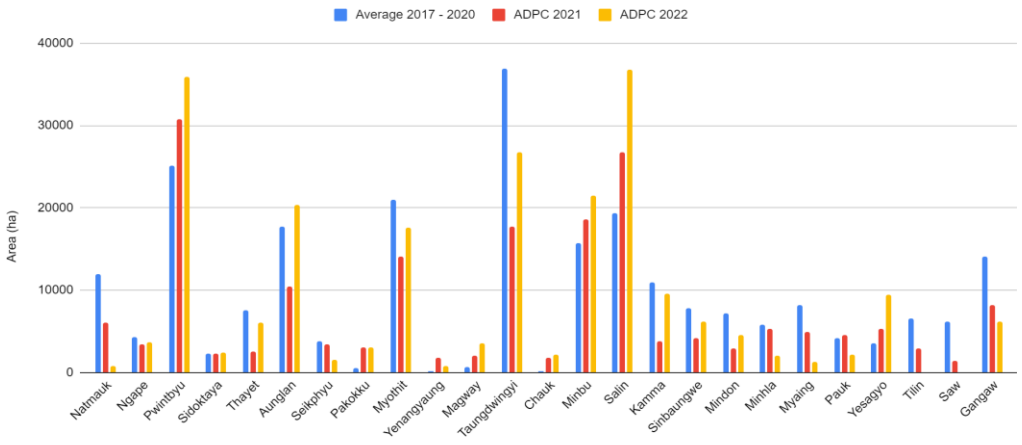


Figure 31. A comparison of Magway rice area by township. The GAD average for 2017–2020 is blue, and ADPC estimates for 2021 and 2022 are red and yellow, respectively.

g) SAGAING REGION

Sagaing is located in northwestern Burma in the country's dry zone and accounted for 13.1 percent of the country's total rice cultivation in the 2022 monsoon season. Rice fields are primarily concentrated in south-eastern townships, where townships in Shwebo district alone contain more than a third of the region's rice area (Figure 32[A]). A full breakdown by township reveals Kanbalu, Kawlin, and Tabayin as having cultivated the most rice overall (Figure 32 [B])

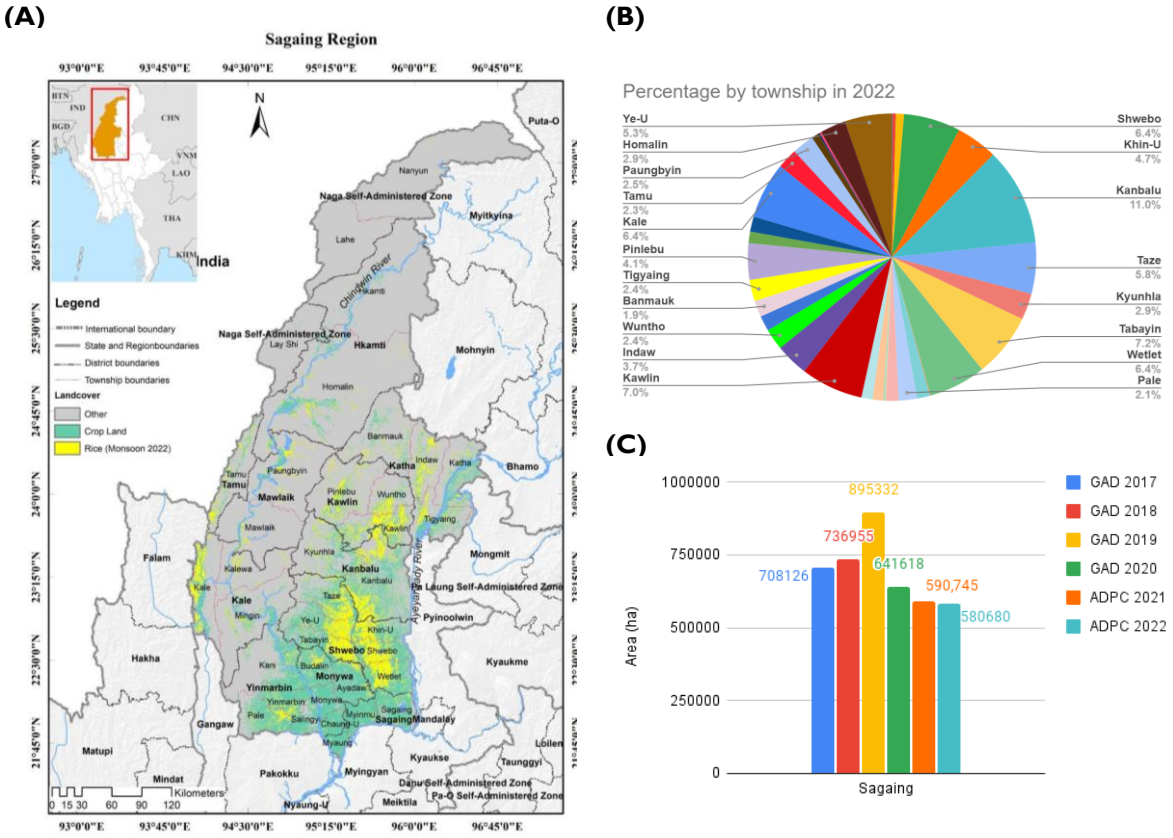


Figure 32. (A) The 2022 monsoon rice area in Sagaing. (B) The rice area breakdown by township. (C) A state-level comparison of 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

After validating these area estimates and adjusting for error, the final state-level estimate for Sagaing is 580,680 ha, with an uncertainty of 4.4 percent. This estimation is 2 percent less than last year's ADPC estimates and 9.5 percent less than GAD's in 2020. Figure 32(C) summarizes the estimates available over recent years.

The rice fraction maps in Figure 33 show where the rice area has changed in terms of respective township area since last year. The townships Indaw, Katha, Kawlin, Shwebo, and Wuntho district townships are a shade deeper than last year, indicating relative gains in area. In terms of loss. Only Chaung-U and Paungbyin are a shade lighter, representing lower area planted

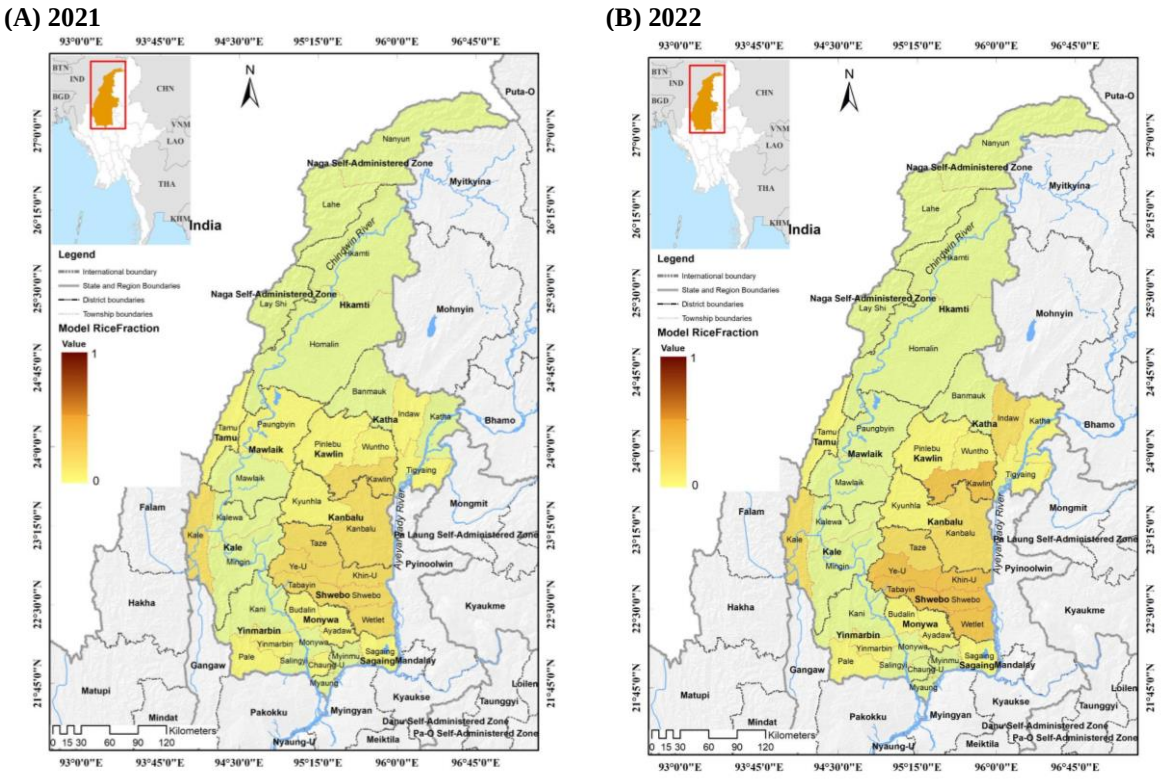


Figure 33. The percentage of rice area planted relative to the total area by township for the monsoon seasons of 2021 (A) and 2022 (B).

Figure 34 visualizes the ADPC rice map areas of loss and gain in 2022 from 2021 according to the spatial distribution. While many of the central townships exhibit some gains, the southern townships that account for the majority of the rice area exhibit losses.

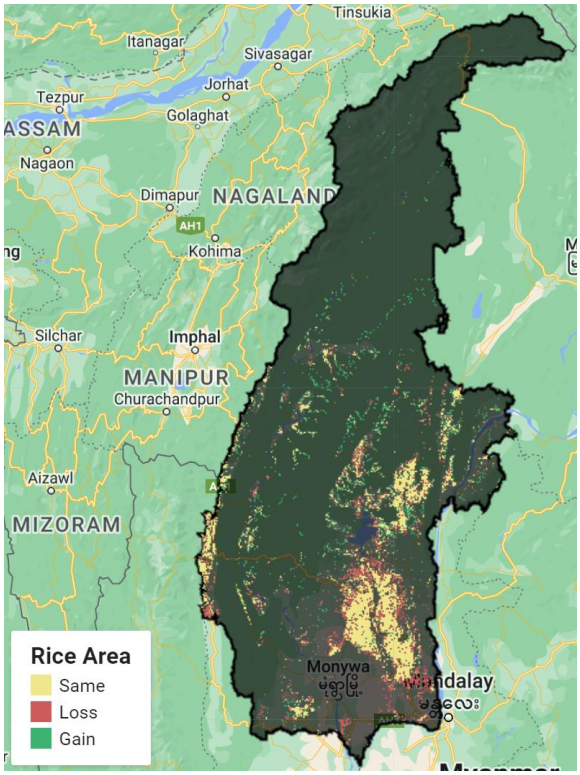


Figure 34. The change in rice area between 2021 and 2022. Yellow areas signify no change in rice area, red areas indicate where there was growth in 2021 lost in 2022, and green areas indicate where there was growth in 2022 gained from 2021.

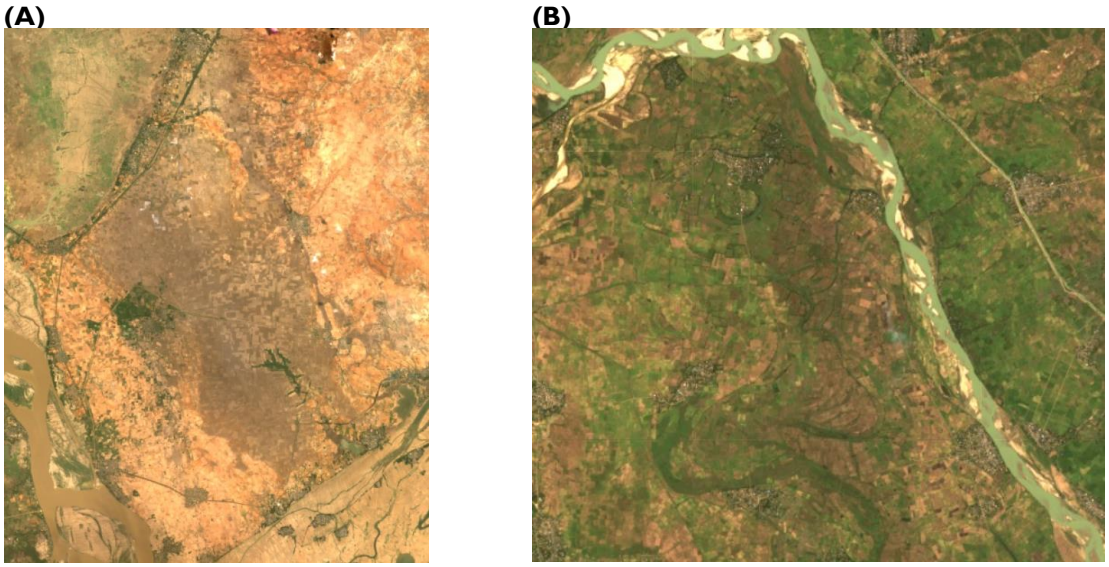


Figure 35. (A) Planet image in September 2022 showing no rice cultivation in 2022 in Chaung-U township. (B) Planet image in Taze township in October 2022 in which green fields are rice and brown fields are not cultivated.

Figure 36 shows a comparison between ADPC's 2022 estimates, its estimates from last year, and an average of historical data available from GAD between 2017 and 2020 by township. In general, estimates show some variation across the years; however, compared to GAD, Wetlet and Khin-U especially show large reductions in 2021 and 2022, while Kawlin, Shwebo, and Tabayin show some increases in area.

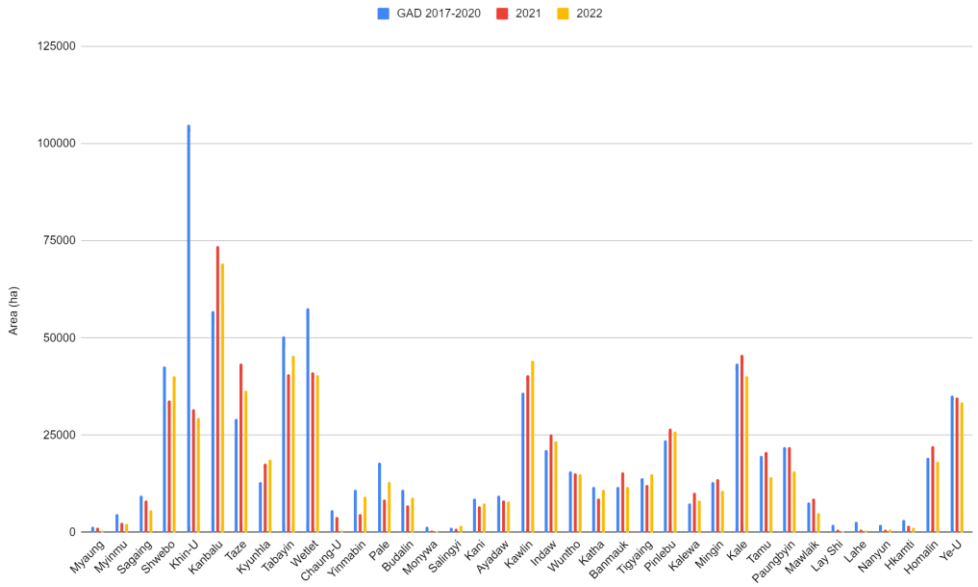


Figure 36. A comparison of Sagaing rice areas by township. The GAD average for 2017–2020 is blue, and ADPC estimates for 2021 and 2022 are red and yellow, respectively.

f) KAYAH STATE

Kayah is located in eastern Burma in the country's hilly zone and contributed 0.5 percent to the country's total rice cultivation in the 2022 monsoon season. Figure 53(A) shows rice concentrated primarily in the northern part of the state, with Demoso and Loikaw accounting for 80 percent of the total area. Figure 53(B) shows a full breakdown by township. ADPC did not estimate Kayah's rice area last monsoon season, so no comparison is included here.

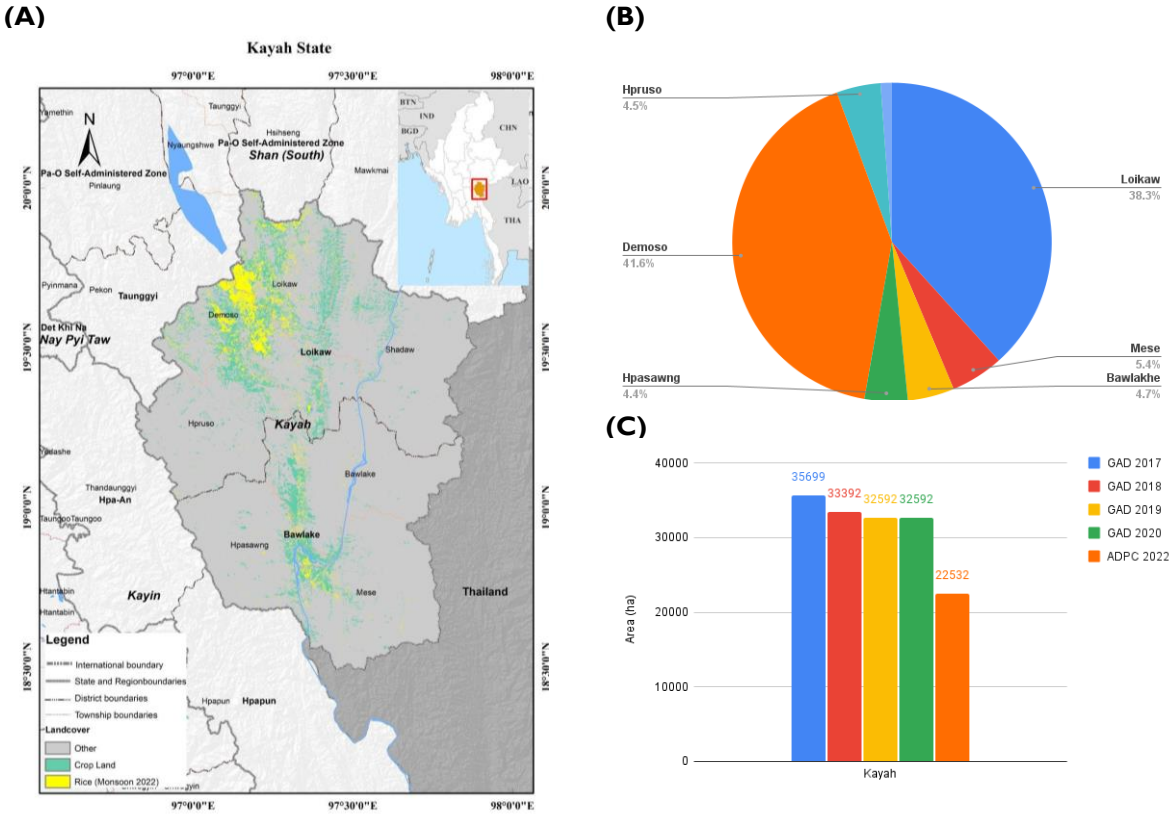


Figure 37. (A) The 2022 monsoon rice area in Kayah. (B) The rice area breakdown by township. (C) A state-level comparison of 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment

After validating and error-adjusting the pixel-level area estimates, Kayah's final total rice area during 2022's monsoon season is 22,532 ha, with an uncertainty of 10 percent. This estimate is 31 percent less than GAD's in 2020. Figure 37(C) summarizes available state-level estimates from recent years. ADPC did not estimate Kayah's rice area last monsoon season, so no comparison is included here.

Figure 38 displays the rice area relative to township in a rice fraction map, where only Demoso and Loikaw show significant rice cultivation.

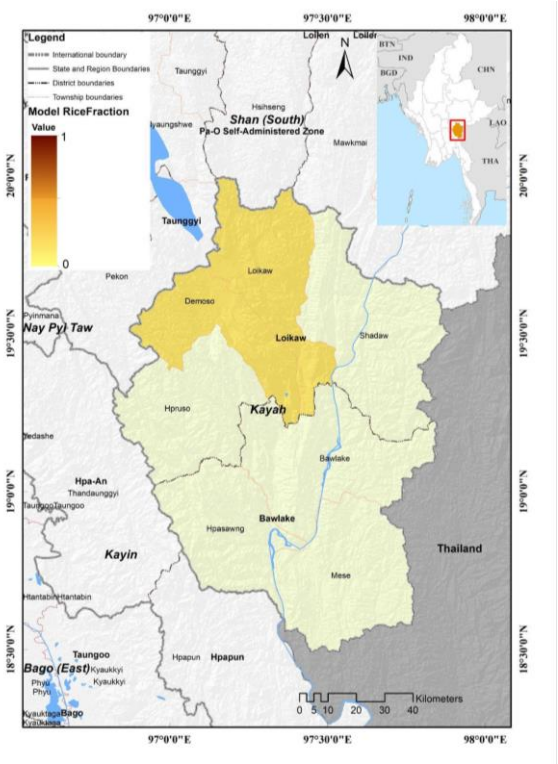


Figure 38. The percentage of rice area planted in Kayah State relative to the total area by township for the 2022 monsoon season.

h) SHAN STATE

Shan State is located in the eastern part of Burma in its hilly zone and is the country's largest state in terms of physical size. All 55 townships cultivated rice this monsoon season and, in total, accounted for 10.6 percent of the country's monsoon rice in 2022. Figure 39(A) maps the distribution of rice in the country, and Figure 39(B) shows the breakdown by township. The majority of rice is cultivated in Shan South, with Hsihseng, Nansang, and Taunggyi individually containing double the area of any other township in Shan North or East.

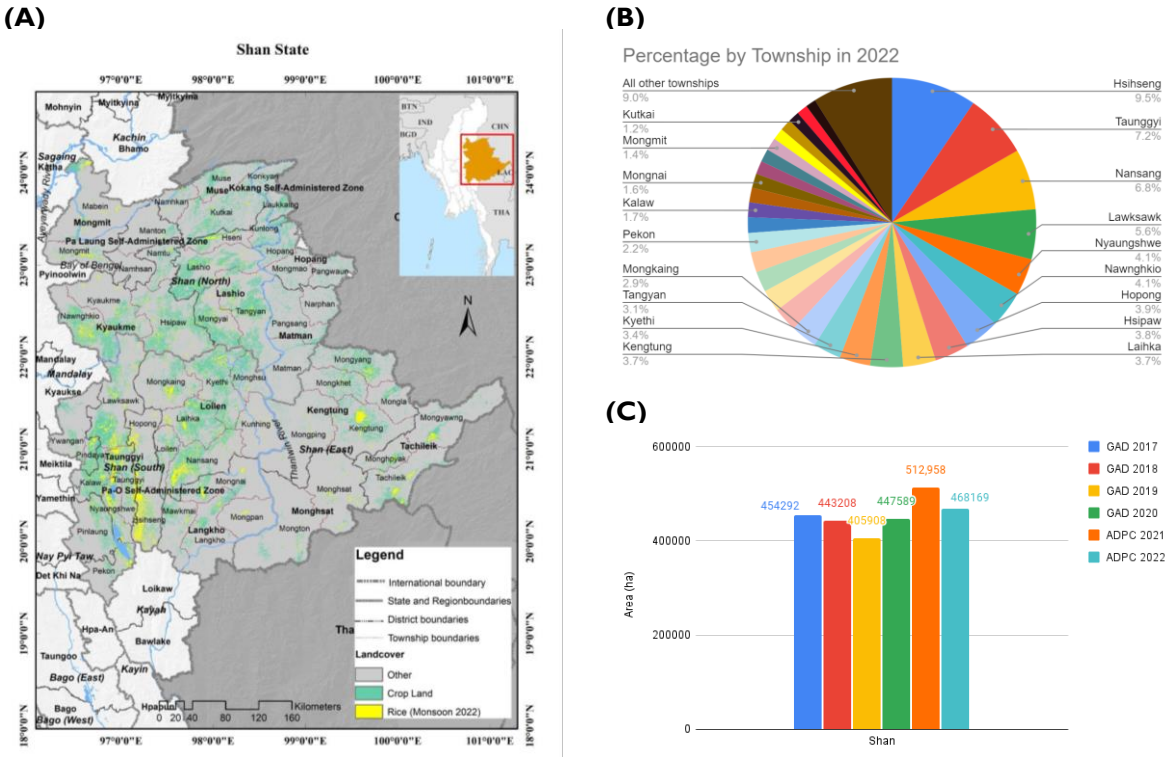


Figure 39. (A) The 2022 monsoon rice area in Shan State. (B) The rice area breakdown by township. (C) A state-level comparison of 2017–2020 GAD values with ADPC estimates in 2021 and 2022 after error adjustment.

After validating and error-adjusting the pixel-level rice estimates, the final state-level estimate for Shan in 2022's monsoon season is 468,169 ha, with an uncertainty of 12.8 percent. The relative high uncertainty is likely due to the state growing various other crop types with phenologies that are not too distinct from rice. ADPC's 2022 estimate is 9 percent lower than its estimate from the previous year and five percent higher than GAD's estimate in 2020. Figure 39(C) summarizes the rice area estimates for Shan state annually since 2017.

Figure 40 shows the rice area of each township relative to its respective area. The majority of townships are a shade lighter than last year, or two shades lighter as in Shan East's Mongyang. Laihka, Namkhan, and Nansang are a shade darker and Shan North's Nawnghio is two shades darker, while the rest of the townships maintained the same color.

(A) 2021 **(B) 2022**

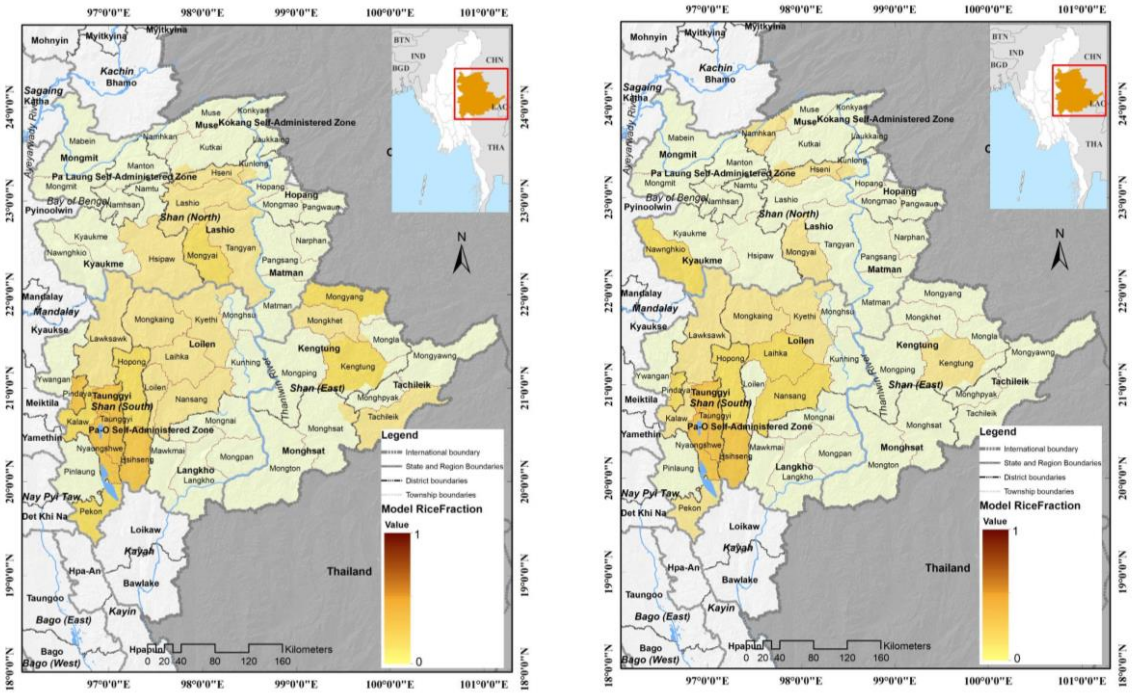


Figure 40. The percentage of rice area planted relative to the total area by township for the monsoon season in 2021 (A) and 2022 (B).

3. MONSOON RICE PRODUCTION ESTIMATION

a) RICE CULTIVATION AREA ESTIMATES

Table 1 shows the total estimated 2022 and 2021 ADPC monsoon rice cultivation area estimate with 90 percent confidence intervals (uncertainty), the GAD's area estimate in 2020, and percentage change in the ADPC estimate for 2022 compared to 2021. The table shows a slight increase in normal rice area for Ayeyarwady and Mon compared to the estimates of last year. Slight reductions were found for Bago, Sagaing, Shan, and Yangon. However, these estimated increases and decreases are within the range of the uncertainty boundaries. Larger reductions were found for Magway, Mandalay and Rakhine. Although unfavorable weather conditions explain the decrease in Rakhine, they do not explain the larger reductions for Magway and Mandalay. The 2021 monsoon estimates for those regions might have been optimistic as the 2020 GAD data shows lower estimates for both regions compared to the 2021 estimates as well. Kayin and Kayah were not included in the 2021 analysis. The current estimates for both states indicate an area of 22,532 ha and 101,309 ha for Kayah and Kayin, respectively. Both numbers are significantly lower than the numbers reported by GAD for 2020. Overall, the total estimated area for the 2022 monsoon season by ADPC is about 4.4 million ha, which is a reduction from the 4.8 million ha estimated for 2021 by ADPC. This represents a 7 percent decrease in the cultivated area in Burma from 2021 to 2022.

Table 1. Area estimates for monsoon rice 2022 cultivation in Burma.

State		GAD area 2020 (ha)	ADPC area 2021 (ha)	ADPC area 2022 (ha)	Difference 2021 to 2022 (%)	Uncertainty 2022 (ha)
Ayeyarwady	Rice	1,384,321	1,043,045	1,126,480	8	61,956
	Deep rice	-	353,247	102,258	-71	33,541
Bago	Rice	990,183	854,024	805,767	-6	43,511
	Deepwater rice	-	44,246	14,190	-68	695
Magway	Rice	247,827	265,059	191,018	-28	13,753
Mandalay	Rice	163,142	198,470	156,002	-21	9,360
Mon	Rice	277,136	187,912	207,684	11	18,069
Rakhine	Rice	396,284	364,220	291,357	-20	11,946
Sagaing	Rice	641,618	590,745	580,680	-2	25,550
Shan	Rice	447,589	512,958	468,169	-9	59,926
Yangon	Rice	372,254	362,050	354,414	-2	23,391
Kayah	Rice	32,592	N/A	22,532	N/A	2,253
Kayin	Rice	167,907	N/A	101,309	N/A	8,003
Total		**5,120,854**	**4,775,976**	**4,421,860**	**-7**	**311,955**

b) RICE PRODUCTION ESTIMATES

The monsoon 2022 rice yield estimates by IFPRI were used to calculate rice production for this season. Rice yield information by state and region was derived from IFPRI, which estimates are based on the results of the Burma Household Welfare Survey that interviewed about 3000 farmers by phone over the country under the framework of the USAID-funded Myanmar Agriculture Policy Support Activity (MAPSA) project in 2022. Table 2 shows IFPRI's yield and ADPC's production estimates for 2021 and 2022, the uncertainty for 2022, as well the percent difference in production between 2021 and 2022. It can be seen that Ayeyarwady, the largest rice-producing region, saw an increase in production by 8 percent compared to 2021. However, all other states and regions experienced a decrease in production due to lower yields and similar or lower cultivated areas. In absolute terms, the reduction is large in Bago and is quite noticeable in Rakhine. The total production was estimated to be 12,567 ± 851 thousand tons, which is lower than the 2021 estimate of 14,381 thousand tons. This is an overall reduction in total rice production of 13 percent in the country.

Table 2. The yield and production estimates for 2022 monsoon rice with uncertainties and compared with the previous year's estimations.

Region/State		Monsoon 2021			Monsoon 2022			2021–2022 Production Difference
		Yield IFPRI	Production ADPC	Uncertainty	Yield IFPRI	Production ADPC	Uncertainty	
		(ton/ha)	(thousand tons)	(thousand tons)	(ton/ha)	(thousand tons)	(thousand tons)	(%)
Ayeyarwady	Rice	2.82	2,941	298	2.81	3,165	174	8
	Deep water rice	1.57	555	102	1.57	161	53	-71
Bago	Rice	3.32	2,835	189	2.97	2,393	129	-16
	Deep water rice	1.57	69	60	1.57	22	1	-68
Magway	Rice	3.71	983	197	3.27	625	45	-36
Mandalay	Rice	3.58	711	160	3.31	516	31	-27
Mon	Rice	2.99	562	56	2.54	528	46	-6
Rakhine	Rice	3.15	1,147	89	2.3	670	27	-42
Sagaing	Rice	3.47	2,050	368	3.13	1,818	80	-11
Shan	Rice	2.88	1,477	423	2.85	1,334	171	-10
Yangon	Rice	2.9	1,050	62	2.83	1,003	66	-4
Kayah	Rice	2.51	N/A	N/A	2.2	50	5	N/A
Kayin	Rice	3.12	N/A	N/A	2.79	283	22	N/A
Total			**14,381**	**2,005**		**12,567**	**851**	**-13**

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