Spatial assessment of sugarcane (Saccharum spp. L.) production to feed the Komenda Sugar Factory, Ghana

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Abstract

Ghana imports about US$ 2 million worth of sugar annually. To address this huge import bill and to take advantage of a growing demand for sugar in the West African sub-region, the Government of Ghana initiated a Sugar Policy. The Government of Ghana, therefore, re-constructed and commissioned the Komenda Sugar Factory in 2016 at a reported cost of US$ 35 million. The Komenda Sugar Factory can process 1,250 tons of sugarcane per day (or 225,000 tons per annum), but was shut down soon after the test run and commissioning. This raised considerable public outcry. Among the numerous reasons that were given, it was widely believed that the factory faced feedstock deficits. This study therefore applied satellite remote sensing and Geographic Information Systems to quantify the potential feedstock supply from current production within the immediate catchment of the factory. Supervised classification was applied to Landsat 8 images, using QGIS, to quantify sugarcane production in the study area and at specified buffer distances from the factory. The results showed that the factory could mobilize only 7% of its feedstock requirement within the...
industrially recommended radius of 40 miles and 13% within the entire catchment area in the 2016/2017 season. Thus, under current scale of production and production conditions, the Komenda Sugar Factory faces large deficits in feedstock supply. National production data suggests that total national sugarcane production in 2016 would only meet 68% of the factory’s requirement if it were operational. The results suggest an urgent need to establish a plantation for the factory and to commit out-growers to production to support and sustain the factory if it is to become operational soon. There is also a need for high-yielding, high-brix, and early maturing varieties, coupled with good agronomic practices, to bridge the quantity and (potentially) quality gaps.

Keywords: Agriculture, Environmental science

1. Introduction

Sugar is a crystalline substance used mainly as a sweetener in food, beverages and confectionary in both domestic and industrial settings. In 2016, global sugar production was estimated at approximately 169 million metric tons (International Sugar Organization, 2018), with a forecasted production of 179.64 million metric tons for 2017/2018 (Statista, 2018). Currently, Brazil is the leading sugar producer and exporter in the world (International Sugar Organization, 2018), with a total production of 39.15 million metric tons and export of 28.15 million metric tons (Statista, 2018). The top 10 producers currently account for 76% of global sugar production (International Sugar Organization, 2018) and there is no African country on this list. Africa is largely a net importer of sugar, with few countries exporting small quantities of sugar.

Ghana started producing sugar in the 60s at Asutsuare and Komenda. National sugarcane production increased substantially from 1966 (40,000 tons) to a peak in 1977 (270,000 tons), with highest yield of 53 tons ha\(^{-1}\) occurring in 1973 (see Fig. 1). Both yield and production have declined and remained low since 1977 (see Fig. 1). Sugar production in Ghana stopped in the early 80s, which coincides with the period that had the lowest production and yields since 1977. After the collapse of the sugar factories, domestic sugarcane production shrunk dramatically and sugar import increased consistently. Currently, annual total sugar imports to Ghana is about 700,000 metric tons, at a cost of nearly US$ 2 million (Ghanaweb, 2016). In 2013, refined sugar was the second largest food commodity import to Ghana (after rice) in terms of quantity, and the third largest food commodity in terms of value (FAOSTAT, 2014). In response to the current high volume and cost of sugar import, as well as the growing demand in the West African sub-region (e.g. Nigeria imports nearly 2 million metric tons of raw sugar annually; International Sugar Organization, 2018), the Ministry of Trade and Industry initiated a Sugar Policy aimed at
coordinating and deepening domestic interest and investment in sugar production capacity. As a result, the Government of Ghana rebuilt and commissioned the Komenda Sugar Factory in 2016 at a reported cost of US$ 35 million to contribute to the goal of this initiative (Ghanaweb, 2016; The Africa Report, 2016). The design capacity of the new Komenda Sugar Factory is 1,250 tons of sugarcane per day.

Sugarcane (Saccharum spp. L.) is a semi-perennial crop that is used mainly for sugar and ethanol production, as well as for food and feed (Duveiller et al., 2013). It accounts for about 80% of global sugar production, with Brazil being the world’s leading producer, followed by India (International Sugar Organization, 2018). Reliable supply of sugarcane (feedstock) in sufficient quantity and quality is crucial to the sustainability of the Komenda Sugar Factory. It is important to quantify the sugarcane production in the immediate catchment of the factory, as sugarcane at distant locations can increase the cost of transportation and rate of postharvest deterioration (Adami et al., 2012). To this end, the integration of remote sensing and Geographic Information Systems (GIS) becomes a powerful tool for mapping, quantifying and monitoring sugarcane production (Mahlein, 2016; Gebbers and Adamchuk, 2010) within the catchment of the factory to support further policy, operational and management decisions. Satellite remote sensing and GIS are used globally to quantify the spatial coverage and biomass production of crops and other vegetative cover classes (Morel et al., 2014). With reference to sugarcane, satellite remote sensing has been applied to map different varieties (Fortes and Dematte, 2006; Galvão et al., 2005), map and separate sugarcane from other land cover classes (Romani et al., 2011; Rudorff et al., 2010; Xavier et al., 2006), monitor growing and harvest practices (Mulianga et al., 2015; Aguiar et al., 2011), study the phenology and development (Goncalves et al., 2012; Mobasheri et al., 2010) and to estimate or forecast yields (Morel et al., 2014; Duveiller et al., 2013; Mulianga et al., 2013) of sugarcane. The availability of adequate quantity of sugarcane, in nearby farming communities, to feed the Komenda Sugar Factory has become a subject of public interest in Ghana.
since the factory was shut down immediately after the test run in 2016. This study therefore applied satellite image and spatial analysis to map and quantify sugarcane production within the catchment of the Komenda Sugar Factory to assess potential feedstock supply to the factory.

2. Methods

2.1. Study area

The Komenda Sugar Factory is located near Komenda, a coastal community in the Komenda-Edina-Eguafo-Abrem (KEEA) District of Ghana. The KEEA is between longitude 1° 20’ West and 1° 40’ West and latitude 5° 05' North and 15° North, and bounded by the Atlantic Ocean (Gulf of Guinea) on the south (Ghana Statistical Service, 2014). Apart from the KEEA itself, the nearby districts also produce sugarcane and it is expected that sugarcane from these districts would also feed the factory. The immediate districts that form the catchment of the factory include the Shama District to the west, Mpohor Wassa East District to the north, and the Cape Coast Municipality and the Abura-Asebu-Kwamankese (AAK) District to the east (see Fig. 2). These districts contributed to feedstock supply previously to the erstwhile Komenda Sugar Factory from the 60s to the early 80s. Apart from the northern part of Mpohor Wassa East which falls in the forest zone, the remaining districts largely fall in the coastal savannah agro-ecological zone. There is a major rainy season (March to July) and a minor rainfall season (September to November), followed by a dry period or season (December to February) in the area. Total rainfall ranges between 750 - 1,000 mm in the coastal areas and between 1,200 – 1,500 mm in the hinterlands, with a 30-year average of 1,252 mm (Ghana Statistical Service, 2014; MoFA, 2016). Temperatures are uniformly high throughout the year ranging from 25 - 29 °C (Issaka et al., 2012). With influences from the sea and the forest, relative humidity is moderately high (Issaka et al., 2012). According to the 2010 Housing and Population Census (Ghana Statistical Service, 2018), the Shama, KEEA, Mpohor Wassa East and Abura-Asebu-Kwamankese are largely rural, with Cape Coast Metropolis and Shama District being the most urbanized.

Sugarcane production in the districts immediately surrounding the Komenda Sugar Factory is done by smallholder farmers who currently produce mainly for local distillers. The sugarcane farms are largely non-contiguous, sparsely distributed in landscapes with high spatial and temporal heterogeneities. According to farmers, the main varieties grown are Katuley or Komenda sugarcane (B41227), Alata sugarcane (B36464) and C1000. The B41227 appeared to be the commonest variety used by the farmers. This variety is originally from the West Indies, and was obtained from a cross between B35207 x POJ2878 whose backgrounds are S.
officinarum, S. barberi and S. spontaneum (Mason, 1980). Compared to other varieties, the B41227 is superior in cane, sugar and ratoon yield, as well as suppression of weeds. The major planting starts in March—April (to take advantage of the major rainy season) while minor planting occurs in October—December depending mainly on soil moisture and weather conditions. Maturity period ranges from 10-12 months and main harvesting cycle covers September to April. However, this is not a consistent cycle as farmers grow and harvest sugarcane at different times. Harvesting is done manually (using sharp cutlasses) without pre-burning of straw or
leaves and there is no mechanized production. In the mid-60s to the 70s, sugarcane was the dominant cash crop in the study area due to the presence of industrial sugarcane plantation with a sugar manufacturing industry. It is interesting to note that most of the farmers in these areas grow varieties that were introduced in the 60s to feed the erstwhile sugar factory. Since the collapse of the sugar industry in the 80s, sugarcane production in the study area kept dwindling until it became a minor crop. Few farmers kept growing sugarcane on a limited scale for direct consumption and for local distillers.

2.2. Satellite image acquisition and classification

Two-date multi-spectral Landsat 8 Operational Land Imager (OLI) images were obtained from the USGS Earth Explorer data portal (http://earthexplorer.usgs.gov). The path/row number for the images was 194/056. Two images, dated 31st December 2016 and 8th May 2017, representing the dry and rainy seasons, respectively, were acquired. The Landsat 8 images have eight spectral bands with a pixel resolution of 30 m and an additional panchromatic band (band 8) with 15 m resolution. The images were imported and preprocessed in QGIS Desktop (version 2.18). The images were orthorectified and projected to UTM Zone 30N based on the WGS84 Geographic Coordinate System. The Semi-Automatic Classification Plugin (SCP) was used to apply the dark object subtraction (DOS1) method and to convert the at-sensor radiances to surface reflectance. According to Chavez (1996), the DOS is a suite of image-based atmospheric correction methods that rely on the assumption that the at-sensor radiances of some completely shadowed pixels in a given image are due to atmospheric scattering. For such pixels, a minimum of 1% reflectance (instead of zero reflectance) is assumed since there are very few features on the Earth’s surface that are absolutely black. Details of the DOS method as implemented in the SCP can be found in Congedo (2018). The SCP algorithm uses parameter information from the image metadata (MTL) file which is automatically downloaded together with the Landsat 8 OLI image. Subsequently, band-stacking was applied to the image to enable multi-spectral analysis. The processes for image classification and analysis are presented in the workflow diagram (Fig. 3).

An extensive field campaign was conducted in June—July 2017 to identify and map homogenous sugarcane fields that can be used as training sites. The field data were collected with a Trimble Juno 3B handheld GPS (Trimble™, USA). The field data (both polygons and points) were imported in QGIS and used as training sites and for validation, respectively. Where necessary, additional training sites were digitized on the image as region of interests (ROIs). In most cases, the training sites were selected using the region growing tool (adjusting the spectral distance iteratively to capture the variability in the ROI) within the field-mapped training polygons.
The advantage of using the region growing tool is that it minimizes the standard deviations of the signatures for different bands and thereby minimizes class similarities or overlaps between signatures of different ROIs. Google Earth was also used as a backdrop to provide spatial detail for the identification and selection of some training sites. The identification of training sites was further aided by a chief farmer (who also assisted with field campaign) with rich experience in field management of sugarcane from the 1960s and knows the geography of sugarcane in the study area. Six main classes were defined for the image classification: settlement, bare ground, forest, water, sugarcane, and other vegetation (including other crops and managed or unmanaged vegetation). For the sugarcane class, four subclasses (maturing to matured, young, harvested, and partly-harvested) were defined to capture the situation in the field. Cloud and cloud shadow (mainly in the rainy season image) were masked using the region growing tool and added to unclassified pixels. The classification preview tool in the semi-automatic plugin was used to identify areas with large confusion and unclassified pixels. For such areas, either more ROIs were added or some classes were combined. Further, the spectral signatures of the relevant classes were examined and spectral thresholds adjusted to accommodate the required changes and to reduce overlaps between spectral signatures. This was done iteratively until previews of sections of the image showed satisfactory classification. This was done with special focus on discriminating sugarcane fields as much as possible from all other classes. Finally, the spectral distances between the signatures were computed to assess the separability between the ROIs using the Jeffries-Matusita Distance (for which ‘0’ implies identical, and ‘2’ implies different). This similarity index was used as it is specifically useful for the maximum likelihood classification which was applied in the current study. The calculated values were inspected to ensure that there was no significant similarity between a sugarcane Fig. 3. Workflow of image processing, classification and analysis.
field spectral signature and other classes. Classes that were difficult to separate entirely were urban and bare ground but this was not considered important as the focus of the study was to map sugarcane fields. However, the greatest confusion with sugarcane came from fields covered with giant grass, maize and other grasses (these belonged to other vegetation). Finally, the maximum likelihood classification algorithm was applied to the rainy season image to obtain a classified image.

After classifying the rainy season image, the spectral signatures were exported and used to classify the dry season image using the maximum likelihood classification. Subsequently, the classified image for the rainy season was reclassified into a binary image in which sugarcane fields were classified as ‘10’ and all other classes were coded as ‘0’. Similarly, in the dry season image, the sugarcane fields or pixels were reclassified as 10 but other pixels retained their original values. The two images were then overlaid by addition. In the resulting image, pixels with a value of 10 or more were reclassified as sugarcane fields. This was done to maximize the identification of sugarcane fields in the study area independent of the season. Finally, a classified image (or map) of sugarcane fields, together with the other land cover classes, was produced and the total land area covered by each land cover class was calculated. An accuracy assessment was done using the point data (36 points) collected during the field campaign. An overall accuracy of approximately 78% was obtained (see Table 1).

An area of interest for the study (covering the spatial extent of the catchment of the sugar factory and beyond) was then clipped using a rectangular mask drawn on the map canvas (see Fig. 4a). A point layer was created for the central location of the Komenda Sugar Factory using the factory’s geographic coordinates. Five buffers, with distances of 40, 60, 80, 100, and 120 miles, were created around the point layer of the factory to analyze the quantity of sugarcane obtainable within each buffer distance over the study area. For each of the buffers, the classified image was clipped using the respective buffer polygon as a mask (see Fig. 6a). The ‘zonal raster statistics’ of SAGA in the QGIS processing tools was applied to obtain the count of pixels for

| Ground Truth                  | Forest | Water | Urban/Bare Ground | Sugarcane | Other Vegetation | Total |
|-------------------------------|--------|-------|-------------------|-----------|-----------------|-------|
| Image Data                    |        |       |                   |           |                 |       |
| Forest                        | 5      | 0     | 0                 | 1         | 0               | 6     |
| Water                         | 0      | 3     | 0                 | 0         | 0               | 3     |
| Urban/Bare Ground             | 0      | 0     | 5                 | 0         | 0               | 5     |
| Sugarcane                     | 0      | 0     | 0                 | 7         | 2               | 9     |
| Other Vegetation              | 1      | 0     | 0                 | 4         | 8               | 13    |
| **Total**                     | **6**  | **3** | **5**             | **12**    | **10**          | **36**|

Overall Accuracy 0.777778
each land cover class in the clipped buffer images (in order to quantify sugarcane fields within a given buffer distance). To obtain the quantity of sugarcane that can be obtained in the study area and for each buffer distance, the estimated yield of sugarcane (\(\sim 50 \text{ tons ha}^{-1}\), based on current production by smallholder farmers in the study area) was multiplied by the total area of sugarcane fields from the image analysis.

3. Results

The area clipped from the satellite image covers Mankessim in the East, as far as Tarkwa Nsuta in the West, and beyond Assin Fosu in the North (Fig. 4a). This spatial extent is large enough to enclose the districts immediately surrounding the Komenda Sugar Factory and beyond, and from which sugarcane was anticipated to be obtained.

Within the spatial extent of this clipped area, sugarcane production is highly concentrated in the southern part (Fig. 4b). The areas of concentrated sugarcane production include Abura Dunkwa Edumfa area and around Putubiw to Jukwa area (in the Abura-Asebu-Kwamankese District) to the north of Cape Coast Municipality, Kissi and Abrem area in the KEEA District, and Daboase-Shama-Inchaban area in the Shama District. The sugarcane production also seems to be more concentrated in the west of the Komenda Sugar Factory (in the Shama District) than the east of the factory. Sugarcane production decreases considerably northwards from the areas of concentration. The image analysis shows that this area of interest is dominated by vegetation other than sugarcane, followed by forest (Fig. 4c). The total quantity of sugarcane obtained within this study area was 29,750 tons (Fig. 4c).

Because the total sugarcane yield or production was low in the clipped area of interest, we quantified the total sugarcane production in the entire image scene, which stretches from the coast of central region to the edge of Kumasi (just beyond Lake Bosomtwi) in the Ashanti Region. For the whole image scene, the total sugarcane production was 101,700 tons (Fig. 5). Again, other vegetation dominated the land cover classes in the image.

Finally, five buffers of distances ranging from 40 to 120 mile, at 20 mile intervals, were created to assess the quantity of sugarcane that can be obtained within each buffer distance (see Fig. 6a for sample buffer). For each buffer, the classified image was clipped to the cutline of the buffer (see Fig. 6a) and the land cover classes were quantified. The analysis shows that within the industrially recommended radius of 40 miles from the factory, only 15,757 tons of sugarcane could be obtained (Fig. 6b). This is approximately 53% of the total sugarcane obtained within the clipped study area and approximately 15.5% of the total obtained within the area covered by an entire image. Within 80-mile radius (double of the industrially recommended radius), a total of approximately 45,100 tons of sugarcane could be obtained.
Even though an overall accuracy of 78% (Table 1) was obtained, it was visible from the classified image that areas dominated with grass-like vegetation presented the greatest confusion. We exemplify this misclassification with Fig. 7a. The area around the western part of the Fosu Lagoon in Cape Coast (circled black) indicates the presence of sugarcane. However, while this area has very few stands of unmanaged sugarcane, it is not entirely sugarcane as indicated in the image. The area is dominated by grasses. This suggests potential overestimation of the sugarcane production. Principally, giant grass caused the largest confusion as it looks similar (visually and spectrally) to sugarcane (see Fig. 7b).

4. Discussion

4.1. Feedstock deficit

Sugarcane accounts for about 80% of global sugar production (International Sugar Organization, 2018). The Komenda Sugar Factory has a design capacity of 1,250 tons of sugarcane per day. For a 180-day operational cycle, the factory would require 225,000—300,000 tons of sugarcane per annum. While manual surveys of few farms could have been used to estimate sugarcane supply potential in the area, mapping and estimating current sugarcane supply potential with satellite remote sensing offers a more rapid, wide coverage and less expensive approach for planning the plantation.
and daily operations of the Komenda Sugar Factory. This is important given the spatially and temporally heterogeneous land uses or landscapes associated with sugarcane production in the study area (Mulianga et al., 2015).

The current study estimated the sugarcane production in the catchment of the Komenda Sugar Factory. The results indicated that, potentially, the total sugarcane production in the immediate catchment of the factory (based on the clipped area of interest) from late 2016 to mid-2017 amounts to approximately 30,000 tons (Fig. 4). This is only 13% of the factory’s requirement, suggesting that if the factory were operational, it would have a feedstock deficit of about 195,000 tons and it would be operating far less under its capacity. Further, it is industrially recommended that sugarcane production to supply feedstock to a sugar factory occurs as close as possible to the factory, ideally within a 40-mile radius. This is to minimize...
biochemical changes that can adversely affect the quality and/or quantity of sugar production, as well as to minimize transportation cost (Adami et al., 2012). In the current study, however, within the industrially recommended 40-mile radius, the total sugarcane that could potentially be mobilized was 15,757 tons (amounting to only 7% of the factory’s annual requirement). By doubling the industrially recommended radius to 80 miles, total sugarcane production was approximately 45,100 tons (about 20% of the factory’s requirement). Finally, the total sugarcane potentially produced in the entire area covered by one Landsat 8 (OLI) image would amount to about 45% of the factory’s requirement. This suggests that the Komenda Sugar Factory faces substantial feedstock deficit. Based on the potential feedstock obtainable from the current study, even if a 20% production potential is added to the current estimates (due to the overall classification accuracy obtained), the factory would still have a large deficit. The deficit indicated in the current study might even be worse as not all the varieties currently grown by the farmers might be suitable for sugar

Fig. 7. Exemplifying a misclassification and its cause. A: Grasses misclassified as sugarcane in the area west of the Fosu Lagoon in Cape Coast. B: Image showing giant grass (B1 and B2) and sugarcane (B3) in the background.
production. Some of the varieties might have low brix and might be unsuitable or unprofitable for the factory. Further, the yield value (50 tons ha\(^{-1}\)) used to estimate potential production or supply in the current study was obtained from interactions with distillers, farmers, and some staff members of the factory and this might be inaccurate. Considering the estimated yield of sugarcane in Ghana as at 2016 (see Fig. 1; FAOSTAT, 2014), the yield value used in the current study could potentially overestimate the total production. Fig. 1 shows that average sugarcane yield has remained under 30 tons ha\(^{-1}\) since 1986.

The reconstruction and inauguration of the Komenda Sugar Factory generated considerable public interest due to the internal imperatives for industrialization, job creation and value addition to especially agricultural produce (Ghanaweb, 2016). The people in the immediate catchment of the factory were especially excited about the huge prospects of jobs and income generation from the operation of the factory (Ghanaweb, 2016). As a result, the closure of the factory soon after the test run became a topical issue to all classes of Ghanaians. While proponents and opponents advanced various reasons for the closure of the factory, the issue of adequate feedstock supply became an important component of the speculation that was widely believed. Indeed, inadequate feedstock supply could be a major reason for the shutdown of the factory. As the current study shows, there is not sufficient sugarcane to meet half the capacity of the factory. Sugarcane production in Ghana was highest in the late 60s to early 70s (FAOSTAT, 2014; Fig. 1) when both the Komenda and Asutsuare sugar factories were operational. Sugarcane production (both in terms of area cultivated and total harvest) fell rapidly after the collapse of the sugar factories in the 80s. Since then, largely local distillers and direct consumption of cane juice have sustained sugarcane production on a limited scale. In 2016, the total sugarcane production in Ghana was 152,136 tons, with an average yield under 30 tons ha\(^{-1}\) (FAOSTAT, 2014; Fig. 1). This indicates that current sugarcane production in Ghana is low, reinforcing the feedstock deficits that the Komenda Sugar Factory faces currently.

Climatic and soil conditions in the catchment of the factory are suitable for sugarcane production and a greater part of these areas were under sugarcane production from the 60s until the early 80s. An analysis of likely areas where sugarcane production or expansion can occur (restricting forest conversion and eliminating urban areas and water bodies) was done within the buffer zones. This analysis showed that within a 60-mile radius of the factory, potentially, sufficient land can be obtained to produce about 50% of the factory’s requirement under current production conditions and yields (Fig. 8). However, within 80 miles, if potentially available land is committed to sugarcane production, then the factory’s requirement can be met under current production conditions and yields. This raises two issues for policy and/or the factory’s operators. First, a swift action is required to secure sufficient land within reasonable distance from the factory to produce sugarcane for the factory. The factory requires a
plantation to serve as a base to which out-grower supplies can be added. This is important to ensure that the factory does not shut down when out-growers divert their produce to other buyers. Second, effort should be made to persuade potential out-growers to keep or actually commit their land and resources to sugarcane production to feed the factory. Currently, the factory faces a land use competition from other large scale, commercial agricultural production activities in the area. For example, there is a hint of large-scale rice production in the Central Region with support from the Korean Government (Daily Graphic, 2017). This activity can extend to potential sugarcane production areas. It is important that the Komenda Sugar Factory addresses this potential land use competition by securing sufficient land for its own plantation and for out-growers. These two issues also point to the need for varieties and agronomic management practices that will help bridge the quantitative and qualitative gap in feedstock supply. If high-yielding varieties are introduced in tandem with good agronomic management practices, it could be possible to meet the factory’s feedstock requirement within about 60-mile radius. For example, a variety that yields about 70 tons ha\(^{-1}\) can results in a total production of 182,630 tons on potential lands within a 60-mile radius. However, intensification would also be necessary to minimize cost of transporting feedstock from afar. This suggests a need for high-yielding, high-brix varieties and the application of good agronomic practices to sustain intensive production to supply feedstock to the factory.

### 4.2. Accuracy of the estimates

Use of optical satellite image analysis for quantifying landscape variables is associated with uncertainty. Accuracy assessment helps quantify the degree to which pixels of target variables are accurately classified. In the current study, our interest was mainly in the accuracy of identifying and quantifying sugarcane fields and were less concerned with confusion between any two non-sugarcane pixels. The overall accuracy for the current study was approximately 78%. However, the user
and producer accuracies for sugarcane fields were approximately 83 and 79%, respectively. These values are acceptable. Mulianga et al. (2015) applied spectral indices derived from time series Landsat 8 (OLI) images to map sugarcane fields in the Kibos-Miwani Sugar Zone, Kenya. They obtained an overall accuracy of approximately 84%, with producer and user accuracies of approximately 80% and 96%, respectively, for sugarcane. The producer accuracy obtained for sugarcane in the current study is not different from that obtained by Mulianga et al. (2015) even though the user accuracies are quite different. Further, the overall accuracy in the current study is slightly lower than that of Mulianga et al. (2015). The sugarcane fields in the current study are much more heterogeneous than those in the study by Mulianga et al. (2015) as sugarcane was the main crop in the latter study but a minor crop in the former study. As indicated earlier, the major confusion with sugarcane came from fields with good cover of mainly giant grass and maize (Fig. 7b). This, together with the asynchronous planting and harvesting practices, makes mapping of sugarcane using remote sensing challenging. The 30 m spatial resolution of the Landsat image, compared to the small and heterogeneous sugarcane fields, might also contribute to the accuracy obtained in the current study (Mulianga et al., 2015, 2013). However, even though there is an overall error of about 20% in the classification, this is not likely to significantly alter the fact of large deficit in feedstock supply facing the Komenda Sugar Factory.

5. Conclusion

Estimates of sugarcane feedstock that can be obtained around the Komenda Sugar Factory is crucial for policy, operational and management decisions, as well as the sustainability of the factory. To restart and sustain the operations of the Komenda Sugar Factory, feedstock supply in sufficient quantity and quality and on sustainable basis is crucial. The current study integrated satellite remote sensing and GIS to estimate sugarcane production to feed the Komenda Sugar Factory. The results show that the Komenda Sugar Factory faces large deficits in feedstock supply. Within the industrially recommended radius of 40 miles, the factory can mobilize only 7% of sugarcane based on current production conditions and yield. Within the spatial extent of the entire catchment of the factory, the factory would not be able to obtain enough feedstock to operate at half capacity. It is quite interesting to note that the national sugarcane production in 2016 (based on FAOSTAT data) would satisfy approximately 68% of the factory’s requirement. A swift action is required to establish a plantation for the factory and to commit out-growers to sugarcane production if the factory is to become operational soon. There is also an urgent need to bridge the yield (and potentially quality) gap by introducing appropriate varieties coupled with good agronomic management practices. Infrastructure development will also be required to facilitate quick transportation of feedstock to the factory.
Declarations

Author contribution statement

David Yawson, Michael Adu, Kingsley Osei: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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