DECCMA

Working Paper

Biophysical and Socioeconomic State of the Volta Delta Region of Ghana from the Perspectives of Gender and Spatial Relations

Prince Osei-Wusu Adjei[1], Ignacio Cazcarro[2], Iñaki Arto[3], Patrick K. Ofori-Danson[4], Joseph K. Asenso[5], Samuel Nii Codjoe[6], Kwasi Appeaning Addo[7] and Samuel K. Amponsah[8]

1 Kwame Nkrumah University of Science and Technology, Kumasi, Ghana
2,3 BC3-Basque Centre for Climate Change, Spain
4,6 University of Ghana, Legon, Ghana
5 Ministry of Finance and Economic Planning, Ghana

CARIAA
Collaborative Adaptation Research Initiative in Africa and Asia

IDRC | CRDI
International Development Research Centre
Centre de recherches pour le développement international

Canada

UKaid

Citation:
Adjei et al, 2018. Biophysical and Socioeconomic State of the Volta Delta Region of Ghana from the Perspectives of Gender and Spatial Relations. DECCMA Working Paper, Deltas, Vulnerability and Climate Change: Migration and Adaptation, IDRC Project Number 107642. Available online at: www.deccma.com, date accessed

About DECCMA Working Papers

This series is based on the work of the Deltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA) project, funded by Canada's International Development Research Centre (IDRC) and the UK's Department for International Development (DFID) through the **Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA)**. CARIAA aims to build the resilience of vulnerable populations and their livelihoods in three climate change hot spots in Africa and Asia. The program supports collaborative research to inform adaptation policy and practice.

Titles in this series are intended to share initial findings and lessons from research studies commissioned by the program. Papers are intended to foster exchange and dialogue within science and policy circles concerned with climate change adaptation in vulnerability hotspots. As an interim output of the DECCMA project, they have not undergone an external review process. Opinions stated are those of the author(s) and do not necessarily reflect the policies or opinions of IDRC, DFID, or partners. Feedback is welcomed as a means to strengthen these works: some may later be revised for peer-reviewed publication.

Contact
Prince Osei-Wuju Adjei
princeosei2@hotmail.com

Creative Commons License

Abstract

This paper provides insights into the current socioeconomic and biophysical state of the Volta Delta, Ghana. Hybrid and non-survey methods, notably the Flegg Location Quotient (FLQ) method of regionalization and construction of tables, are used to develop environmentally extended input-output (IO) model for comparing the economic characteristics of the Volta Delta region and the rest of the country. The main sources of data for doing the regionalization were the District Analytical Reports. Results from the study indicate that the agricultural sector, trade and transport activities are much predominant in the delta than in the non-delta region. However, employment in services of public administration, financial and insurance, construction and crop production is higher in the non-delta than in the delta region. From a gendered perspective, the embodied work of women in the delta is high in services and manufacturing sectors, but less predominant in agriculture and fishing (compared to the male's participation). Overall, the delta was found to be a net importer (embodied in goods and services from other regions, higher than in exports) of all the metrics used in the study, including agricultural land use, employment, energy and CO_2 emissions.

1.0 Introduction

The Volta Delta located at the lower part of the Volta basin with about 181 towns and villages is inhabited predominantly by farmers and fishermen. In recent times, the Volta Delta Region of Ghana and other similar Delta regions worldwide have come under intense climate change effects with likely socioeconomic implications. As a result, migration has become a major response to this development in these regions which continue to attract research attention. As part of the DEltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA) research project, it is considered necessary to construct a global economic model that is able to capture the economic impacts of climate change in the delta areas based on the Global Trade Analysis Project (GTAP) - Computable General Equilibrium (CGE) model.

This economic model is to allow policy makers to see how different climate scenarios affect the economic options in the delta regions of Ghana, India and Bangladesh being studied under the DECCMA project, and how these in turn affect the vulnerability and sustainability of the Deltas. It is recognized however that, before the construction of the economic model, which is broadly the primary objective of Work Package Four under the DECCMA Project, it is necessary to understand the biophysical and socioeconomic context of the three Delta regions. This is to provide a systematic overview of the structure and functioning of the socioeconomic and biophysical landscape prevailing in the regions.

Against this background, this working paper is intended to produce some insights of the baseline and the present state of the Volta Delta with emphasis on the socioeconomic and biophysical context, its spatial relations and interdependencies with the economics through the supply chain up to the final demand of goods and services within the delta, in the rest of the country (Non-Delta) and in the rest of the world (RoW). The paper is structured in five sections.

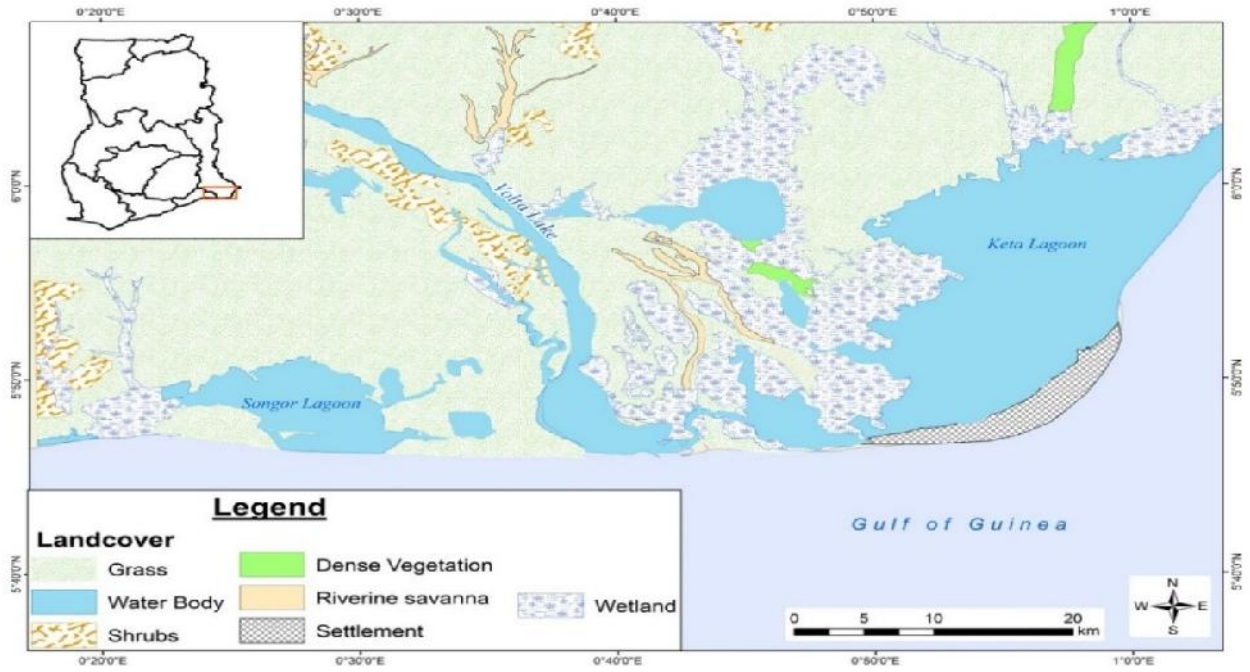
The section one looks at the background to the study. In the section 2, we present the context of the delta. Left in the Appendix 4 the Methodology, Section 3 summarizes it. Section 4 shows the Results, which consist of three parts. The first part is the comparison of Distribution of Value Added in the Delta and non-Delta. The second part is the Labour and gender embodiments in the final consumption of goods and services, both within the country (delta and non-Delta) and in the Rest of the world. The third part is the other environmental implications, such as the land and environmental embodiments and footprints. Section 5 presents the Conclusions and discussion.

2.0 Geophysical Context and Site Description

The Volta Delta region constituting the DECCMA study area covers a total area of about 3,301km^2 with an estimated total population of 863,810. The area falls within the geological setting referred to as the Keta basin between Latitudes 6^o 8' and 5^o 45' North and longitude 0^o 17' and 1^o 5' East. The basin is filled with 870m of Paleozoic marine and non-marine sediments. This soft geology generally comprises quaternary rocks and unconsolidated sediments made up of clay, loose sand and gravel deposits (Akpati, 1978). The Volta River System, the main source of sediment supply to this basin before the construction of the Akosombo dam in the 1960s, consists of a larger drainage basin, broad delta plain, narrow shelf, steep upper slope, and a large basin floor. The Volta Delta lies primarily in the coastal savannah zone. Its vegetation is primarily swampy, interspersed with short grassland and clumps of bush and trees, mangrove areas and the savannah woodland. Figure 1 shows the physical map of the Volta Delta Region with the different land cover characteristics.

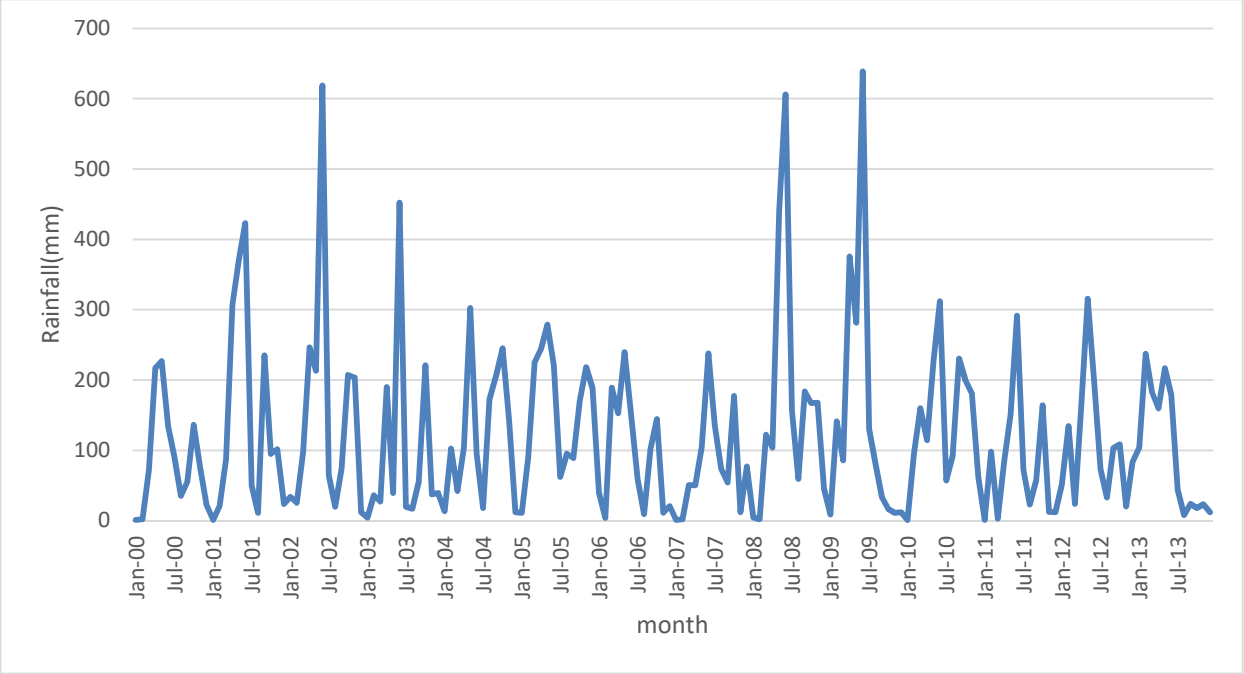
With regard to its climatic conditions, the Volta Delta lies within the wet semi-equatorial and the dry equatorial climatic zones. The climatic conditions of the region are influenced by the Southwest monsoon winds twice a year resulting in a double maximum rainfall pattern: the major rainy season which falls between March and July, and the minor season beginning in August and ending in November. The annual average precipitation of the region varies between 146mm and 750mm. From November to February, the north eastern harmattan winds dominate, giving rise to a long dry season in the region (Awadzi *et al*., 2008; Allersma and Tilsman, 1993). Genera*lly,* it is observed from longitudinal data on the Volta delta that rainfall levels in the region are highly erratic. Rainfall levels are high in the major and minor raining seasons and low in the dry seasons (refer to Figure 2). Between 2000 and 2013 for example, the maximum rainfall level observed was 639mm and the minimum was 1 mm.

Figure 1: Map of the Volta Delta Region depicting the extent of the study site (region within the red line) and physical/land cover Map of the delta.



Source: DECCMA WP2 team at Geodata (Southampton)

Figure 2: Rainfall patterns in the Volta Delta from 2000 to 2013



Source: Ghana Meteorological Agency (2014).

Temperatures in the Volta Delta are relatively high with mean monthly temperature of about 30ºC in the warmest month (March) and about 26ºC in the coldest month (August).

The population distribution of districts in the Volta Delta area are shown in Table 1. It must be emphasized that, the boundaries of some of the districts (e.g. North Tongu, Ketu) extend beyond the delta area.

Table 1: Population Distribution in the Districts of the Volta Delta Region

District	Male	Female	Total
South Tongu	40,019	47,931	**87,950**
Keta Municipal	68,556	79,062	**147,618**
North Tongu	42,492	47,285	**89,777**
Akatsi South	45,497	53,187	**98, 684**
Ketu South	75,648	85,108	**160,756**
Ada East	34,671	37,659	**71,671**
Ada West	28,579	30,545	**59,124**
Total	**335,462**	**380777**	**616,896**

Source: 2010 Population and Housing Census. Ghana Statistical Service.

3.0 Methodology

As described in detail in the Appendix 4, we place the focus on the insights for regionalization and construction of tables for the study of Deltaic areas, under the DECCMA. In particular, we firstly describe the general approach taken for all deltas, which consists in gathering socioeconomic and biophysical information to develop the Environmentally extended input-output (IO) tables and models, distinguishing the (DECCMA definition[1] of the) Delta and the Rest of the country (without the delta, which for simplicity we will call "Non-Delta", while we will call "Rest of the world" the vectors referred to the exports to and imports from of other countries). Then, we focus on the particularities of the construction of the input-output table of this delta, such as the hybrid methods used, departing from the non-survey method of regionalization and construction of tables, the Flegg Location Quotient (FLQ) method. This is used to develop an environmentally extended input-output (IO) model for comparing the economic characteristics of the Volta Delta region and the rest of the country. This allows studying elements such as labour, gender, land, environmental embodiments and footprints. In order to study the effects of alterations such as demand changes or climate change in these areas, interdisciplinary knowledge and models were required. These allow one, for example with a classic model of Leontief demand, to see how domestic demand (households, private institutions, government etc.) and external (exports) requirements influence levels of labour and resource use, which may well find availability limits. The results then shown in the following section have been obtained using the input-output tables and the models associated to them, in particular in combination with the socioeconomic and biophysical extensions/accounts.

4.0 Results and Discussion

4.1 Distribution of Value Addition

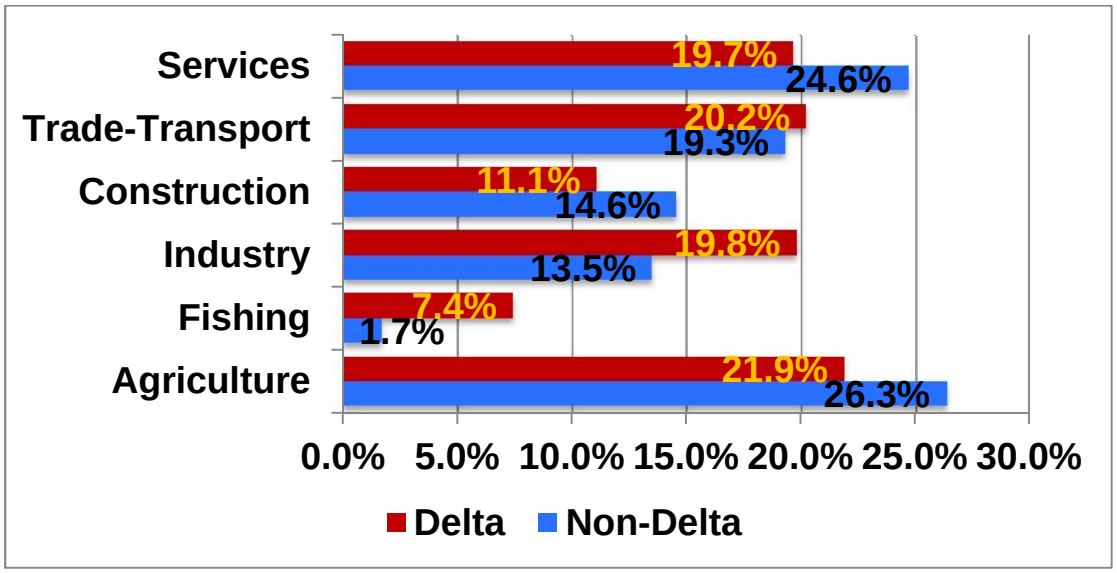
Following the methodology provided in the Appendix 4, the results in Figures 4 and 5 are based on aggregations of 6 and 16 sectors respectively, out of the 57 sectors of GTAP 9. The results from the simulation reveal the importance of the agricultural sector, which accounts for approximately 21.9 percent of the delta's economy. Agriculture is also found to constitute the largest share of the non-delta economy, with a share of 26.3 percent, as shown in Figure 4. This is a clear indication that agricultural activities elsewhere in the country are more pronounced than in the delta. Fishing was found to have a higher share of the delta economy (7.4%) than in the non-delta economy (1.7%). This is also a clear testament that the

[1] 5 meter contour.

inhabitants of the delta, given its location at the Volta Lake catchment area, are more predisposed to engage in fishing than the non-delta.

The results confirm available data that the delta and non-delta economies are service-oriented (i.e. when Services and Trade-Transport are combined). Given the informal nature of both the delta and non-delta, it is not surprising that apart from agriculture, trade occupies a predominant aspect of economic life particularly within the delta. Trade has an intense linkage with transportation and other services so it follows logically that this sector is also predominant. The contribution of construction is also significant in the delta (11.1%) and non-delta (14.6%), which underscores the labour dynamics of Ghana's economy.

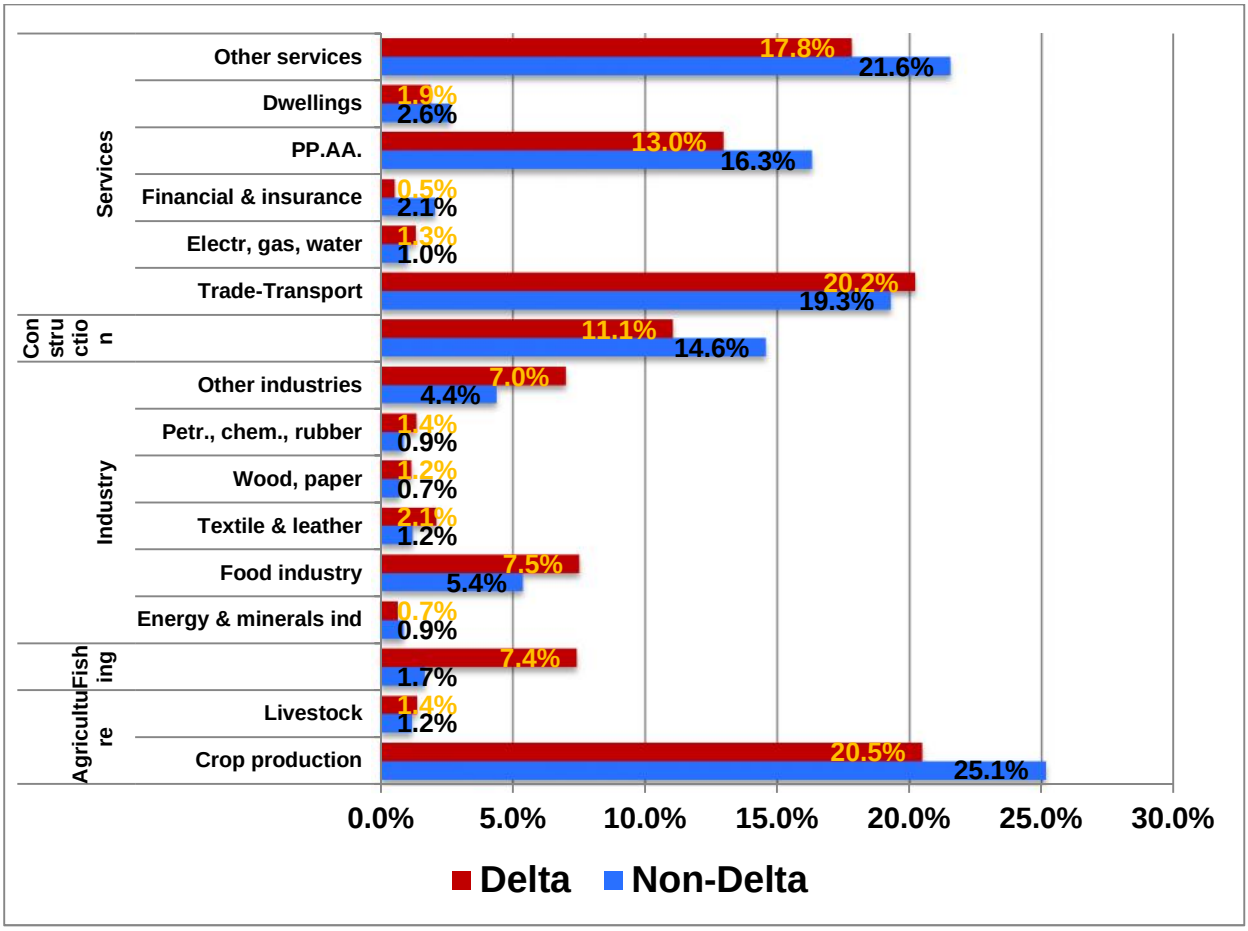
Figure 3. Distribution of Value Added across the 6 main sectors of the Volta Delta



Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country.

A further disaggregation into 16 sectors confirms the results in Figure 3 and reveals the subsectors which drive the contributions of the 6 main sectors shown in Figure 3. Crop production is found to constitute the bigger share of agriculture, compared with livestock, as shown in Figure 4. The results show that crop production is more pronounced, in relative terms, in the non-delta than within the delta. This is consistent with the fact that the food basket of the country is the middle and upper belts of the country, as compared to the coastal belt, while the coastal belt (where the delta is located) is known for its dominant fishing activities.

Figure 4. Distribution of Value Added by 16 main sectors of the Volta Delta.

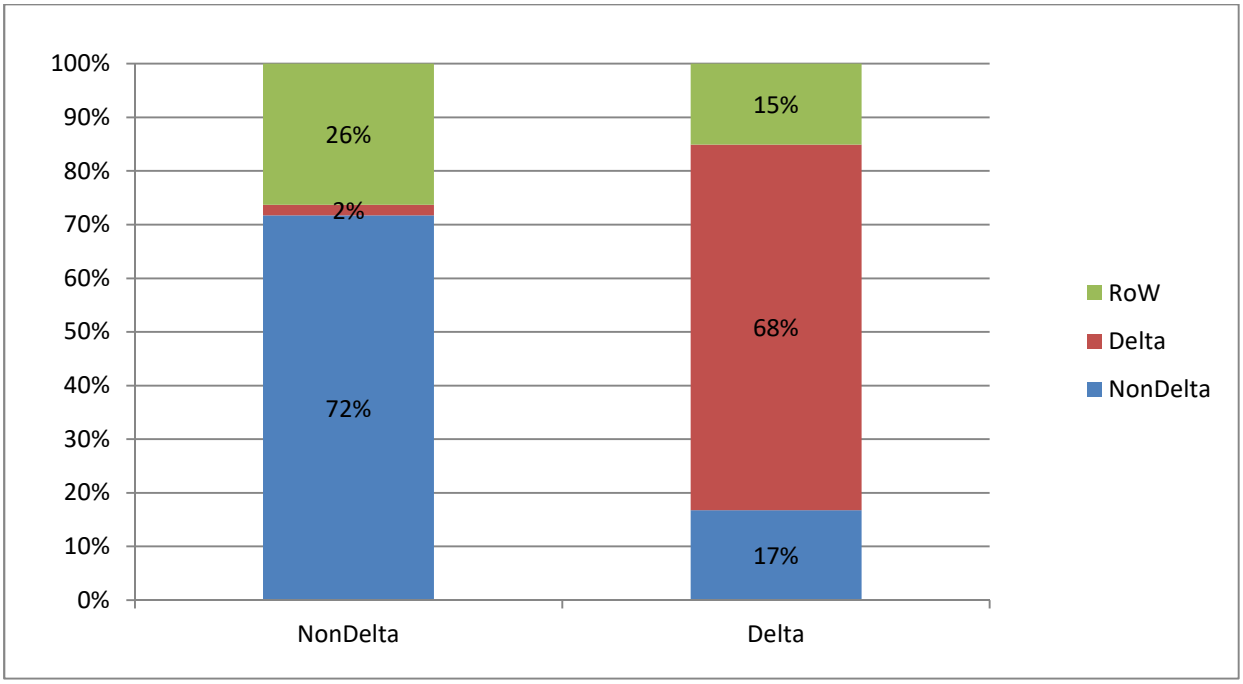


Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

4.2 Labour and gender embodiments

The discussion below focuses on the level of employment created by the respective regions (delta and non-delta) for labour force of the delta, non-delta and RoW. The results in Figure 5a reveal that about 72 percent of non-delta labour produces to satisfy the final demand of the non-delta itself, 2 percent to satisfy the final demand of the delta region and 26 percent to satisfy the final demand of the RoW. Whereas, about 68 percent of the delta labour produces to satisfy its final demand of the delta itself, 17 percent to satisfy the final demand of the non-delta and 15 percent of labour within the delta produces to satisfy the final demand of the RoW.

Figure 5a: Employment of the delta by demanding region



Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

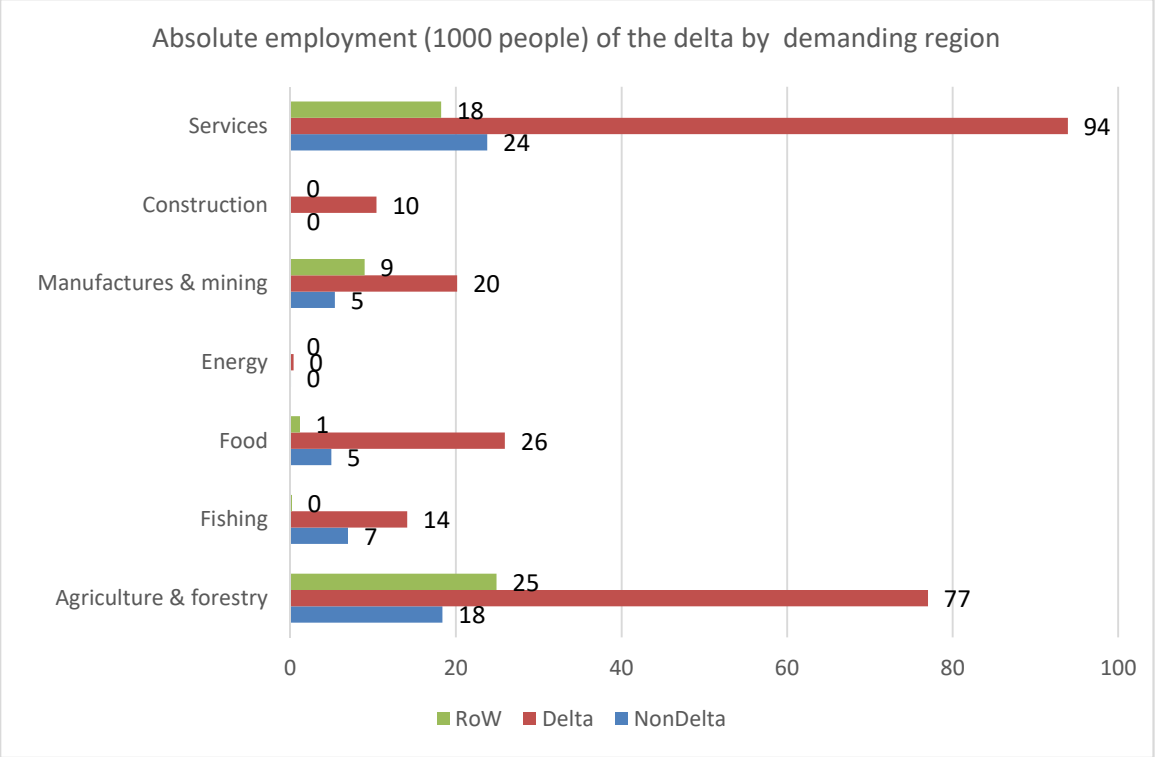
Employment by sector within the delta confirms the results in Figure 5a. The results in Figure 5b indicate that majority of the people (i.e. 94,000) in the service sector within the Volta Delta work to satisfy the final demand of the delta itself, while 24,000 of the people in the service sector work to satisfy the final demand of the non-delta and about 18,000 working to satisfy the final demand of RoW. In the agriculture industry, majority of the people are found to work to satisfy the final demand of the delta itself, followed by the non-delta and RoW, as shown in Figure 5b.

Figure 5a shows the relatively modest contribution of the delta demand in the non-delta employment (as it is a smaller area, while the employment in Ghana is estimated for 2010 in 9,931 thousand people). Still, in absolute terms, it represents an employment of 187,000 people who work to satisfy the final demand of the delta. On the other hand, we observe that employment in the delta (i.e. 355,000 people) has a small proportion (less than 20%, which represents a smaller proportion than in the other deltas being studied under the DECCMA project) that works to satisfy the final demand of the non-delta and the RoW (about 15%, which is a similar share to the one found in the other deltas being studied under the DECCMA project).

On the other hand, it is observed that the labour in the delta that work to satisfy the final demand of the non-delta and RoW constitute a relatively smaller percentage than in the focal deltas of DECCMA (India and Bangladesh).

Figure 5b shows the distribution by sector of employment within the delta. The results show that the labour within the delta, to a large extent, work to satisfy the final demand within the delta itself. This is evident in the Services, Agriculture & Forestry, Food industry and Manufactures & mining sectors. It is also observed that quite a significant number work to satisfy the final demand of the non-delta and RoW in the Agriculture and Forestry as well as Services sectors.

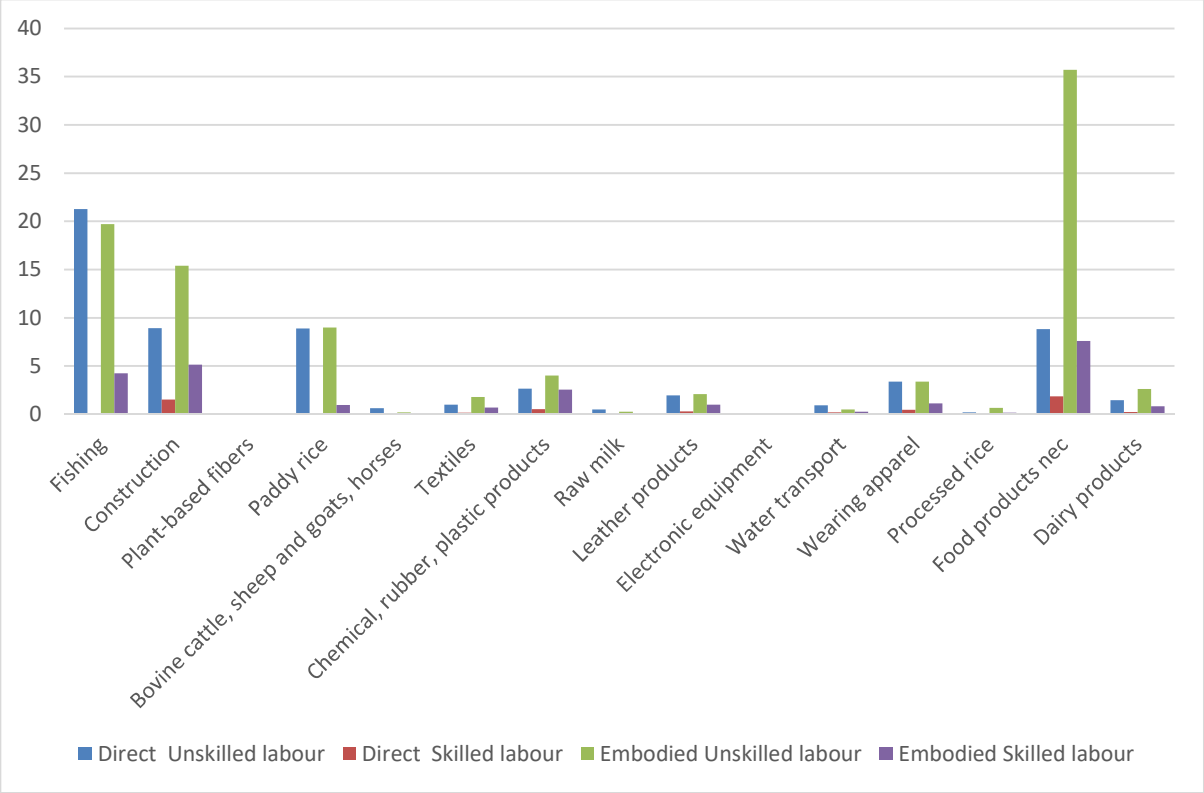
Figure 5b: Employment of the delta by demanding sector



Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

Further, Figure 6 builds on the results shown in Figures 5a and 5b by indicating the distribution of skilled and unskilled labour across industries within the Volta Delta. From the foregoing, embodied unskilled labour is quite active in the Food products nec., while direct unskilled labour is prominent in the fishing industry and paddy rice production. Skilled labour for the two categories are much present in Food products nec. and construction than elsewhere. To a larger extent, this could be due to the technical supervision that these two industries require.

Figure 6 Direct and embodied labour of the delta by sector

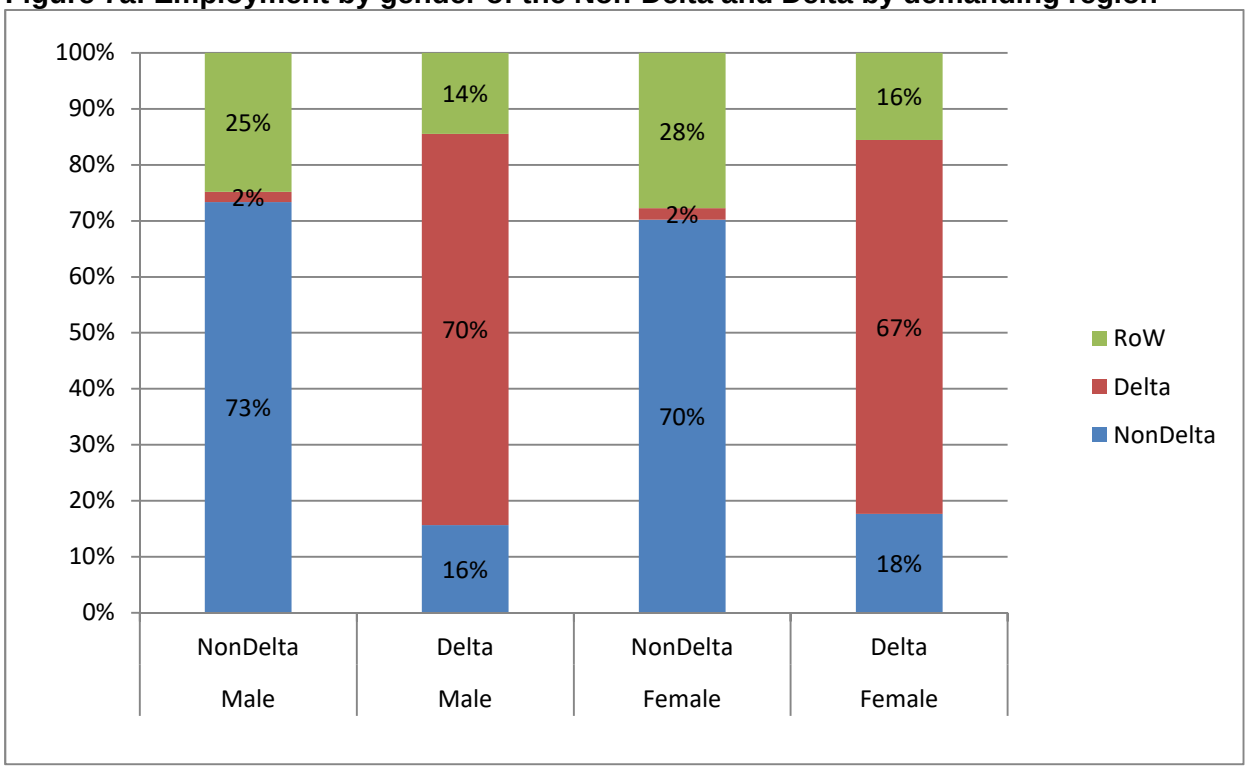


Source: Elaboration from the computations with the IO table and extensions of the Delta

With regard to employment distribution by gender across regions, the results shown in Figure 7a reveal that, out of the total males employed by the non-delta, 73 percent work to satisfy the final demand of the non-delta itself, 25 percent for RoW, while 2 percent to work to satisfy the final demand of the Volta Delta region. Likewise, of the males employed in the delta, 70 percent work to satisfy the final demand of the delta region itself, 14 percent satisfies the final demand of the rest of the RoW and 16 percent, the non-delta. This trend is not different for female employment across the demanding regions. Whilst majority of females within the delta work to satisfy the final demand of the delta itself, majority of females within the non-delta work to satisfy the final demand of the non-delta itself as shown in Table 8a. This implies that in both within the delta and non-delta regions, the different gender categories of labour work to satisfy local consumption.

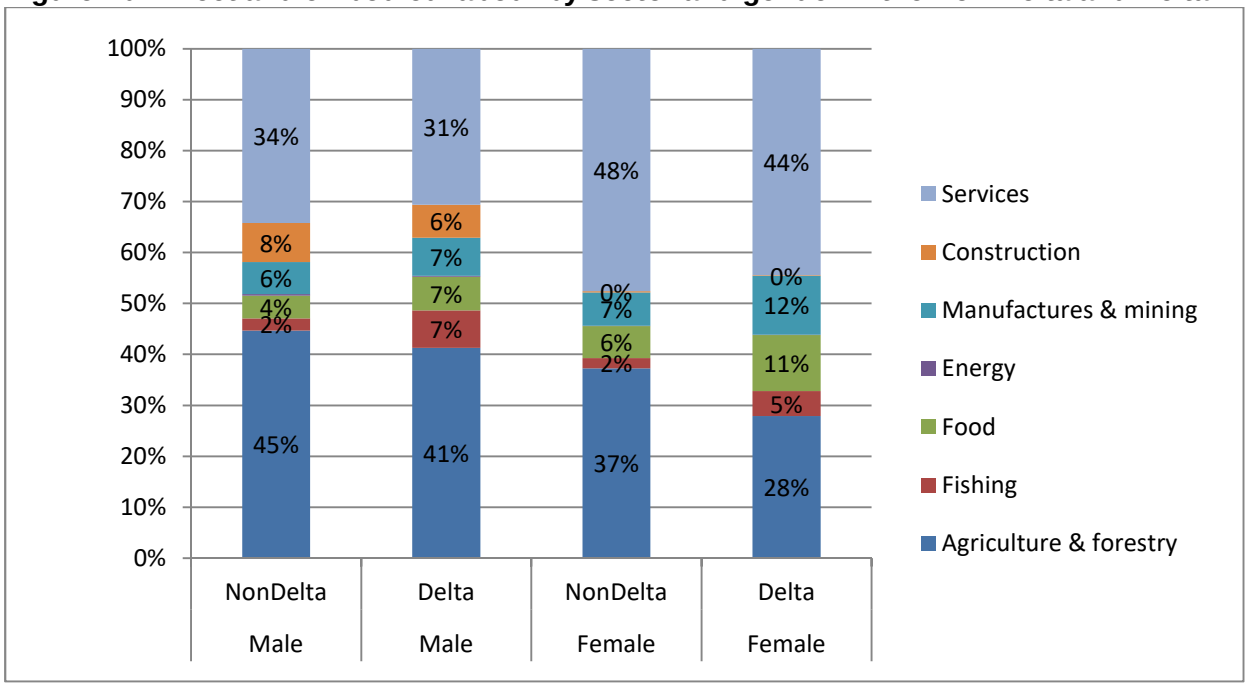
Similarly, Figure 7b shows the distribution of employment by gender in major sectors across the regions. It is quite revealing that agriculture is the number one male employer across the different regions, whilst the service sector employs the most females. Agriculture employs 45 percent of non-delta males and 41 percent of delta males, whilst the service sector employs 48 percent of non-delta females and 44 percent of delta females. The results also reveal that there are no females in the construction sector across regions which may be due to the physically demanding nature of the sector or lack of interest. On the other hand, in the food industry across regions, more women than men are found in relative terms.

Figure 7a: Employment by gender of the Non-Delta and Delta by demanding region



Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

Figure 7b: Direct and embodied labour by sector and gender in the Non-Delta and Delta

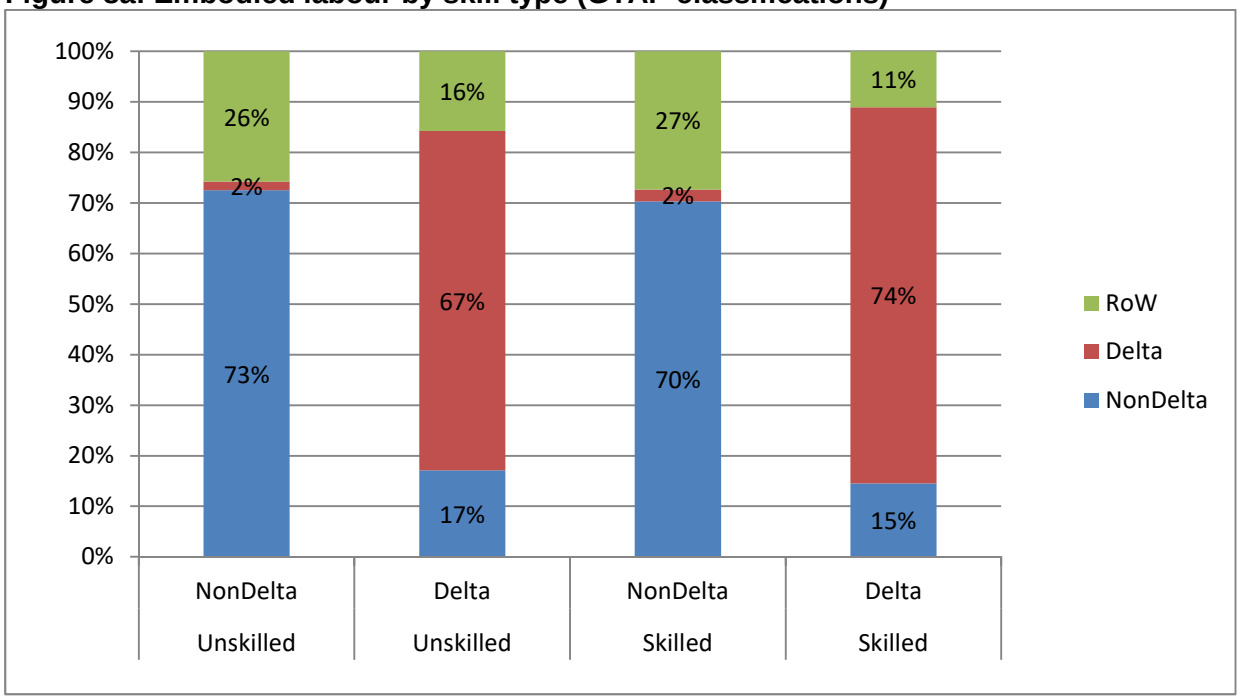


Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country.

Significantly too, Figure 8a reveals that, of the embodied unskilled labour in the non-delta, 73 percent work to satisfy the final demand of the non-delta, 26 percent of the RoW and 2 percent work to satisfy the final demand of the delta. This is quite similar to the distribution of male

workers in the non-delta in shown in Figure 7a. The distribution of unskilled labour also follows a similar pattern as the distribution of male workers in the delta and, the same holds true for the distribution of female workers in the delta and non-delta. The results indicate that, regardless of skills set, labour produces mainly to satisfy domestic demand (within the Volta Delta) than export (i.e. non-delta and RoW). However, the proportion of delta exports to the non-delta is found to be higher than in the other deltas in India and Bangladesh being studied under the DECCMA Project.

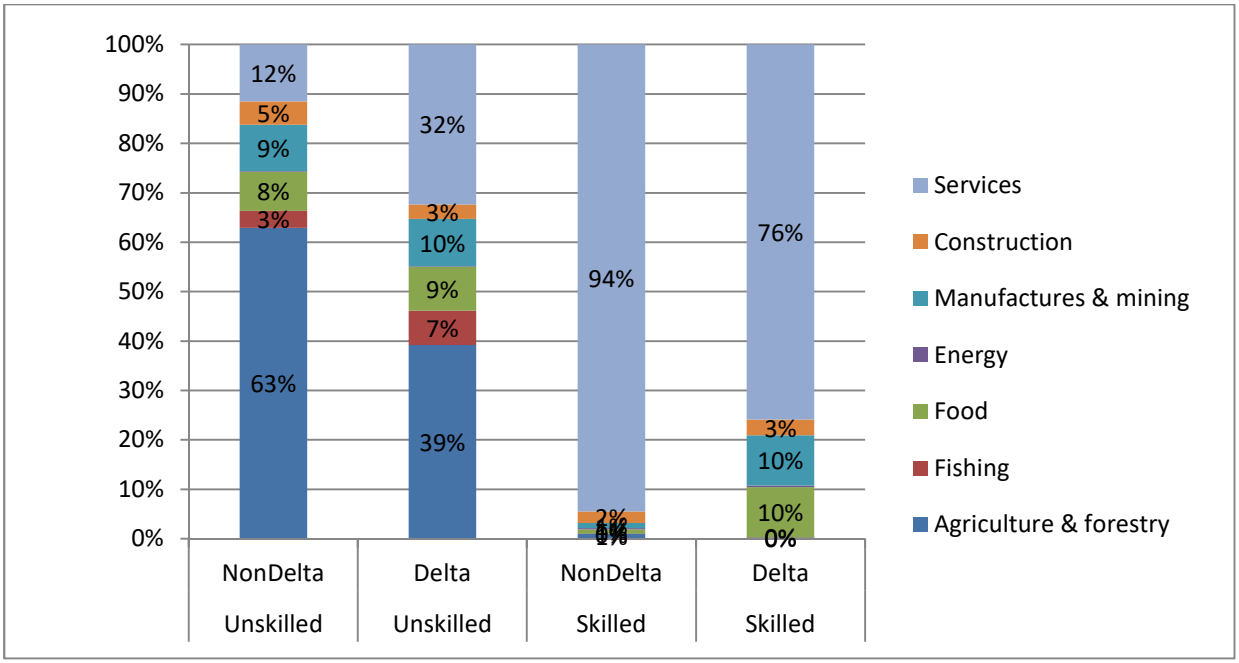
Figure 8a: Embodied labour by skill type (GTAP classifications)



Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

The distribution of embodied labour by sector and skill type reveals that the agricultural sector in the non-delta employs most of the unskilled labour, followed by manufacturing, then mining and food. While the agricultural sector employs most of the embodied unskilled workers in the delta, the services sector is the second largest employer, followed by manufacturing, mining and food. Interestingly, there is hardly any skilled labour in the agricultural sector across regions, with the services sector employing in excess of 90 percent of the embodied skilled labour in both the non-delta and 76 percent in the delta, as shown in Figure 8b.

Figure 8b: Embodied labour by sector and skill type (GTAP classifications)



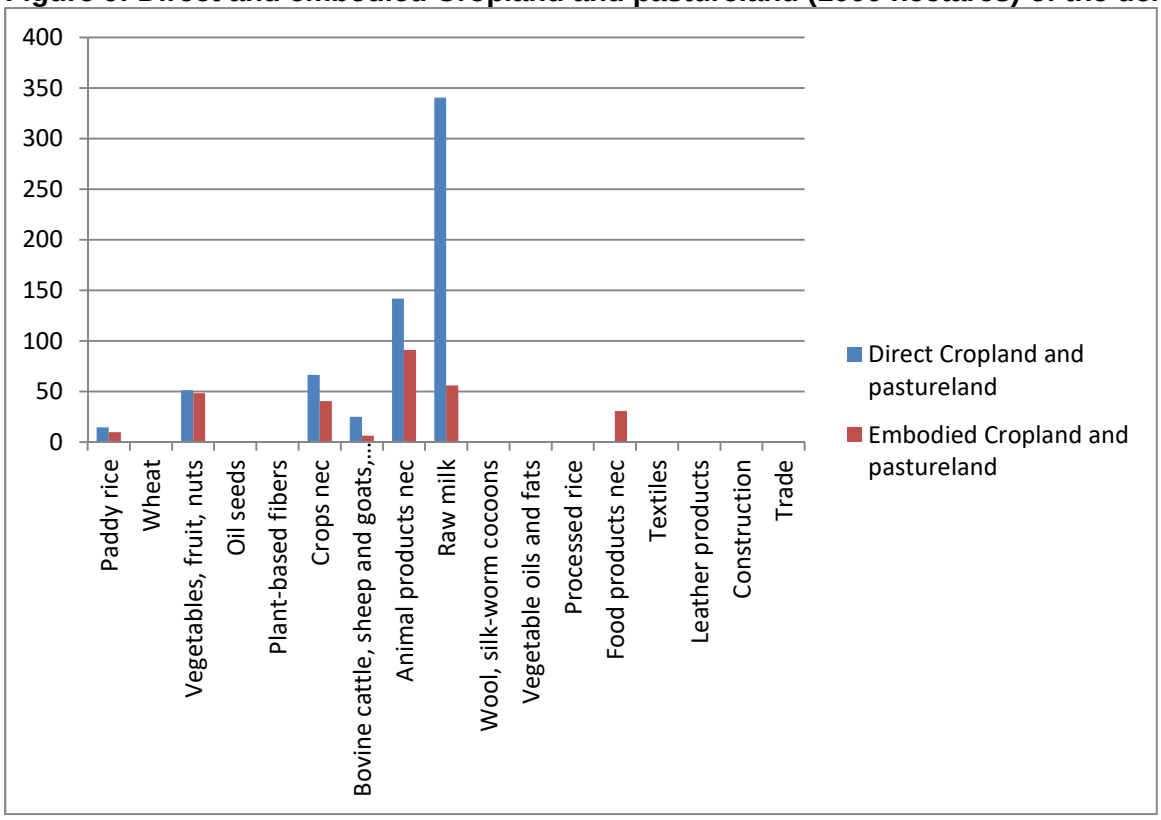
Source: Elaboration from the computations with the IO table and extensions of the Delta

4.3: Land, environmental embodiments and footprints

This section focuses on land use and their impact on the environment. The results shown in Figure 9 relate to the sectoral analysis of labour by examining the land use and environmental impacts. The findings establish that, the direct agricultural land use is clearly dominated by the pastureland, assigned to the production of raw milk, of animal products nec. and others; then also of other crops and vegetables, fruits and nuts.

This changes substantially when compared to the embodied agriculture land in the final demand of goods and services. In particular, it is observed that the embodied land use in the animal products nec. is particularly relevant, mostly occurring to satisfy the exports (final demand of the non-delta and RoW). Furthermore, sectors not directly using agricultural land the most, such as food industry sectors, have notable embodied (directly and indirectly) agricultural land levels.

Figure 9: Direct and embodied Cropland and pastureland (1000 hectares) of the delta



Source: Elaboration from the computations with the IO table and extensions of the Delta

Table 2. Summary of import, export and footprints

	Direct in production	Embodied exports (E)	Embodied imports (M)	Net trade (E-M)	Footprint
Delta. Employment	355	113	318	-205	560
Delta. Land (1000 hectares)	670	222	612	-390	1060
Delta. Energy (Mtoe)	0.1	0.0	0.1	-0.1	0.2
Delta. CO2 (Mt CO2)	0.1	0.0	0.1	-0.1	0.2
Non-Delta. Employment	9,576	2,706	2,624	83	9,493
Non-Delta. Land (1000	17,990	4,618	4,434	184	17,806
Non-Delta. Energy (Mtoe)	2	1	1	0	2
Non-Delta. CO2 (Mt CO2)	2	1	1	0	2

Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

Table 2 summarizes the direct uses of resources and environmental impacts (i.e. CO2 emissions) in production, embodied exports and imports and associated footprint (the embodied use or impact in the final demand of the households of the area –delta or Rest of the country). According to these preliminary results, the Volta Delta region is a net importer

(embodied in higher levels of imported goods and services than exported) of agricultural land, employment, energy and CO_2 emissions. The results in Table 3 summarize the embodied exports and imports between the delta and the non-delta. These results further confirm that, the Volta Delta is also a net importer (embodied in higher levels of imported goods and services than exported), of agricultural land and employment.

Table 3. Summary of import, export and footprints only between the delta area & the Rest of the country

	Direct in production	Embodied exports (E)	Embodied imports (M)	Net trade (E-M)
Delta. Employment (1000 people)	355	60	187	-127
Delta. Land (1000 hectares)	670	175	361	-186
Delta. Energy (Mtoe)	0	0.0	0.0	0.0
Delta. CO2 (Mt CO2)	0	0.0	0.0	0.0
Non-Delta. Employment (1000 people)	9,576	187	60	127
Non-Delta. Land (1000 hectares)	17,990	361	175	186
Non-Delta. Energy (Mtoe)	2	0.0	0.0	0.0
Non-Delta. CO2 (Mt CO2)	2	0.0	0.0	0.0

Source: Elaboration from the computations with the IO table and extensions of the Delta and Rest of the country

5.0 Summary and Conclusion

This working paper has revealed some insights of the baseline, the present state of Volta delta, studied in the project DEltas, vulnerability and Climate Change: Migration and Adaptation (DECCMA). Those insights focused on socioeconomic and biophysical context as shown with the analyses of employment and environmental embodiments and footprints. The input-output (IO) table and model have shown and used interdependencies through the supply chain up to the final demand of goods and services in the delta, in the country and in the Rest of the world.

From this paper, it could be concluded that, even though the Volta Delta economy is diverse, the agricultural sector remains dominant. Notable is the fishing sector, which is relatively much larger than in the rest of the country. Also, trade and transport activities which quite often go unnoticed when highlighting important sectors of the deltas, such as small business trade, etc.,

and interestingly some manufacturing activities, were revealed to be relatively predominant in the Volta delta economy compared to the situation in the rest of the country (non-delta)

Significantly too, the work of females satisfies directly and indirectly slightly less the final demand abroad (both in the non-delta and in the Rest of the World than the work of male). The embodied work of women in the delta is most pronounced in services and manufacturing (including the food industry), while being relatively (with respect to male) less pronounced in agriculture, energy, fishing and construction sectors. Also, compared to the females in the non-delta, the employment in services and agriculture is smaller, and higher in manufacturing (including the food industry) and fishing. In addition, the work of the relatively skilled labour in the delta is embodied in the services (although being this fact even more marked in the non-delta, in a much higher proportion than in other countries studied in DECCMA), while being relatively less pronounced (with respect to the unskilled work) in agriculture and the fishing sectors. In the non-delta, obviously except services, and the construction sector, any other sector has a smaller share of embodied labour than in the delta.

Further, the results on land uses show that agricultural land use is dominated by pastureland, notably in the part assigned to the production of raw milk, but also to animal products nec. and others; then also of other crops and vegetables, fruits and nuts; finding more embodied agriculture land in the final demand of goods and services in the animal products nec. In particular, the embodied land use is also relevant in sectors not particularly having an important direct use, such as food industry sectors.

In conclusion, from these preliminary results, the delta is a net importer (embodied in goods and services from other regions, higher than in exports) of all the metrics studied including agricultural land, employment, energy and CO_2 emissions.

References

Akpati, B.N. (1978). Geologic Structure and Evolution of the Keta Basin, Ghana West Africa. *Geological Society of America Bulletin*, 89, 124-132.

Allersma, E. and W.M.K. *Tilmans 1993* Coastal conditions in West Africa - a review. *Ocean and Coastal Management* 19:199-240.

Awadzi, T. W, Ahiabor, E, Breuning-Madsen, H (2008).The Soil-Land Use System in a Sand Spit Area in the Semi-arid Coastal Savanna region of Ghana- Development, Sustainability and Threats. *West African Journal of Ecology*. 13:132-143

Eskelinen, H. and M. Suorsa. 1980. A note on estimating interindustry flows. *Journal of Regional Science* 20: 261 – 266.

Flegg, A. T. and C. D. Webber. 1997. On the appropriate use of location quotients in generating regional input-output tables: reply,. *Regional Studies* 31: 795 – 805.

Flegg, A. T. and C. D. Webber. 2000. Regional size, regional specialization and the FLQ formula. *Regional Studies* 34: 563– 569.

Flegg, A. T. and T. Tohmo. 2013. A comment on Tobias Kronenberg's "Construction of regional input-output tables using nonsurvey methods: The role of cross-hauling". *International Regional Science Review* 36(2): 235-257.

Flegg, A. T., C. D. Webber, and M. V. Elliot. 1995. On the appropriate use of location quotients in generating regional input-output tables. *Regional Studies* 29: 547 – 561.

Ghana Meteorological Agency (2014). Districts Weather Information. www.meteo.gov.gh

GSS (2014). 2010 Population and Housing Census. (Ada East, Ada West, Akatsi South, Central Tongu, Keta Municipal, Ketu North, Ketu South, Ningo Prampram, North Tongu, South Tongu). District Analytical Reports. Ghana Statistical Service.

ILO. 2015. Yearly indicators. Ghana: "Population census", "Living Standards Survey", "Labour force survey", "Survey of Employment and Earnings": International Labour Organization.

Kanemoto, K., A. Geschke, J. Murray, D. Moran, and M. Lenzen. 2011. Multi Regional Input–Output (MRIO) course. Data foundation. In *The international school of input-output analysis*. Alexandria, Washington.

Lenzen, M., D. Moran, and K. Kanemoto. 2013. Building EORA : A global multi- region input – output database at high country and sector resolution. *Economic Systems Research* 25: 37-41.

Leontief, W. 1936. 'Quantitative Input and Output Relations in the Economic System of the United

States'. *The Review of Economic and Statistics* 18: 105-125.

Leontief, W. 1941. *The Structure of American Economy, 1919-1929. Cambridge, (mors)*: Harvard University Press, (Second Ed. 1951, New York, Oxford University Press).

Leontief, W. 1970. Environmental Repercussions and the Economic Structure: An Input-Output Approach. *The Review of economics and Statistics*: 262-272.

Leontief, W. 1974. Structure of the Wold Economy. *The American Review*: 823-834.

Miller, R. E. and P. D. Blair. 2009. *Input-Output Analysis: Foundations and Extensions Second Edition*. New York: Cambridge University Press.

MOFA (2015). Agricultural Statistics. Statistics, Research and Information Directorate, Ministry of Food and Agriculture, Ghana.

Morrison, W. I. and P. Smith. 1974. Nonsurvey input-output techniques at the small area level: an evaluation. *Journal of Regional Science* 14: 1 – 14.

Narayanan, G., A. A. Badri, and R. McDougall. 2015. *Global Trade, Assistance, and Production: The GTAP 9 Data Base, Center for Global Trade Analysis*. Purdue University.

Sawyer, C. and R. Miller. 1983. Experiments in regionalization of a national input-output table. *Environment and Planning A* 15: 1501 – 1520.

Schaffer, W. and K. Chu. 1969a. Nonsurvey techniques for constructing regional interindustry models. *Papers and Proceedings of the Regional Science Association* 23: 83–101.

Schaffer, W. and K. Chu. 1969b. Simulating regional interindustry models for western states: a program on regional industrial development. In *Discussion Paper No. 14*. Georgia: Georgia Institute of Technology.

Tohmo, T. 2004. New developments in the use of location quotients to estimate regional input-output coefficients and multipliers. *Regional Studies.* 38: 43 – 54.

Appendices

Appendix 1. Codes

Lab: All other workers (previously classified as unskilled in GTAP 8), mgr: Managers and professionals, tec: Technicians and associate professionals, clk: Clerical support workers, srv: Service and sales workers.

Appendix 2. The Delta definition

Districts: Ningo Prampram (former Dangme west), Ada west and Ada east (former Dangme east), Central Tongu, Akatsi South, South Tongu, Keta Municipal, Ketu South and Ketu North.

Appendix 3. The Delta input-output table (aggregated to the main sectors) (Mio USD)

	Non-Delta. Agriculture	Non-Delta. Industry	Non-Delta. Rest (Construction and Services)	Delta. Agriculture	Delta. Industry	Delta. Rest (Construction and Services)	Non-Delta.FD	Delta.FD	Exports	**Total**
Non-Delta. Agriculture	1,247	1,570	192	28	48	3	8,161	154	2,655	**14,058**
Non-Delta. Industry	239	2,395	1,854	2	49	12	6,510	48	5,660	**16,769**
Non-Delta. Rest (Construction & Services)	1,865	4,569	6,929	27	97	112	16,949	283	1,962	**32,792**
Delta. Agriculture	0	5	1	2	81	7	90	290	71	**548**
Delta. Industry	1	35	6	25	138	92	86	417	107	**907**
Delta. Rest (Construction & Services)	6	16	16	107	163	176	25	553	11	**1,073**
Imports	936	3,112	3,751	35	110	117	11,524	116	-19,701	**0**
VA	9,764	5,066	20,042	322	221	556	1,104	11	9,235	**46,322**
Total	**14,058**	**16,769**	**32,792**	**548**	**907**	**1,073**	**44,448**	**1,873**	**0**	**112,469**

* Representation of the commercial account balance.

Appendix 4. Methodology for the Study

A4.1 General approach of the (labour, gender, land, environmental) embodiments and footprints

The general approach taken for the preparation of this working paper is an environmentally extended input-output model. This allows studying elements such as labour, gender, land, environmental embodiments and footprints. In order to study the effects of alterations such as demand changes or climate change in these areas, interdisciplinary knowledge and models were required. These allow one, for example with a classic model of Leontief demand, to see how domestic demand (households, private institutions, government etc.) and external (exports) requirements influence levels of labour and resource use, which may well find availability limits (obviously generating growth limits, etc.).

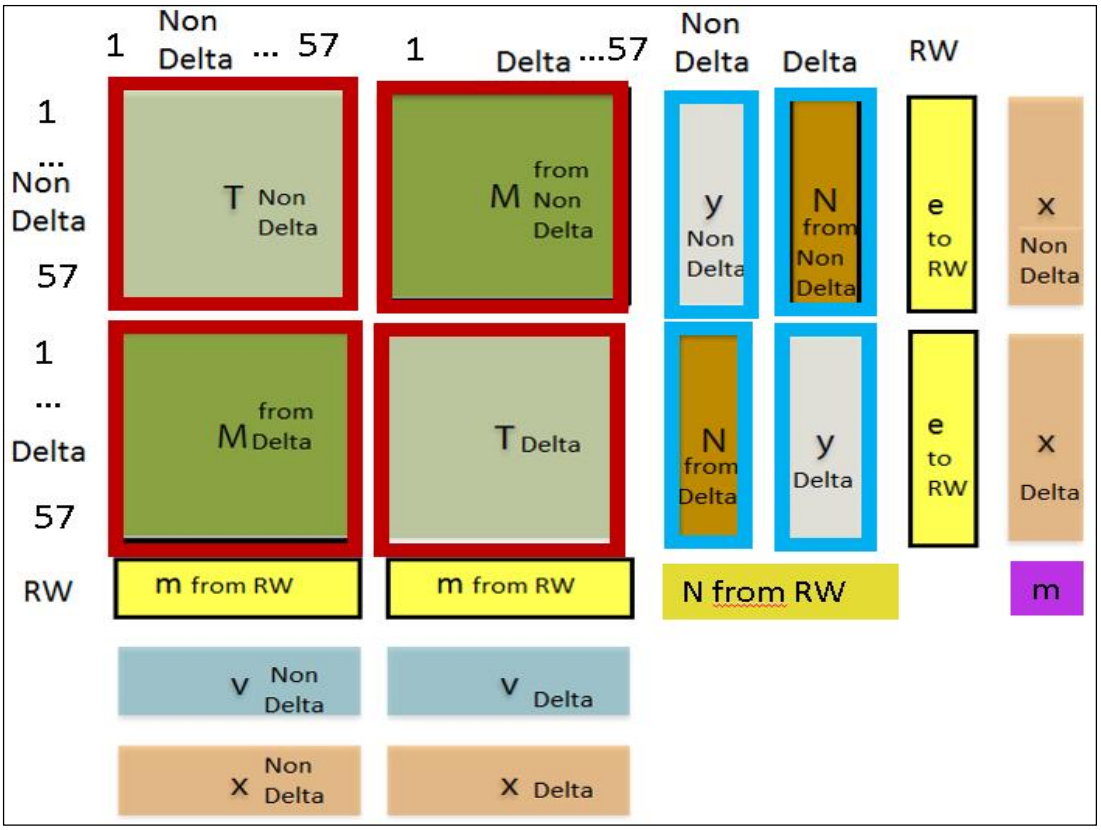
Generally, developing regional tables and extensions of specific Deltaic areas that do not match with the economic or political boundaries, poses additional challenges. As a result, there was much focus on:

- exploration and description of the structure of the economies studied.
- information directed towards the larger or most important sectors of the economies studied and the inclusion of boundaries on some flows.
- the choice of the departure matrix of the surrounding country or region, with an economy similar to the one under consideration and the analysis of the problem of zero location.
- when having to use neighbouring or different scale IO data, identifying similarities rather than differences in regions economic structures.
- the (mis-)match between the political, economic and natural resources (in particular the hydrology defining the Deltas) boundaries and data.

A4.2 Scheme of delta and non-delta input-output table and equations for the model

The scheme used to generate the multiregional input-output table (IOT) for the delta, the rest of the country and the world is shown in Figure ***A4***, where the set of red squares representing transactions of intermediate goods $\mathbf{Z} = (z_{ij})$ and set of blue boxes represents the matrix and **Y** is the vector of final demand. The structure of IOT for the Delta and Non-Delta regions that were needed to be accomplished is shown in Figure ***A4***.

Figure *A4*: MRIO for the Delta and Non-Delta regions.



Source: Adapted from (Kanemoto et al. 2011; Lenzen et al. 2013).

From Figure ***A4***, **T** represents the Intermediate Domestic matrices, **M** the Intermediate Import matrices, **y** the final demand excluding exports of final goods and services to the other region, **N** the final demand of exports (or imports respectively for each region) of goods and services from the other region in the same country, **e** the column vectors of the exports of each of the regions to the rest of the world (RoW), **m** shows the row vectors of the imports of each of the regions from the RoW, **x** is total gross output, and **v** is the Value Added/Primary Input.

Departing from the basic model of Leontief: $\mathbf{x=Ax+y \leftrightarrow x=(I-A)^{-1}y}$ (1)

Where x_i is the gross output of good i; **x** the vector of outputs of the economy; y_i the final demand of goods i; **Y** the matrix of final demand column vectors; $\mathbf{A}=\left(a_{ij}\right)$ the matrix of technical coefficients of the multiregional table indicated above, defined as $a_{ij}=x_{ij}/x_j$ $a_{ij}=z_{ij}/x_j$; finally, $\mathbf{L=(I-A)^{-1}}$ is called Leontief inverse. Being **r**=(r_i) a vector of unitary coefficients of resource (or "input") or impact (employment, land, water, CO2, etc.) per unit of output, we obtain the multipliers, that is to say, the amount of resource directly or indirectly (embodied) per unit of final demand:

$\mathbf{\omega=r'(I-A)^{-1}}$ (2)

So when multiplying these values, the directly and indirectly "required" amounts (used) are obtained, verifying that:

$\mathbf{r'x=r'(I-A)^{-1}y=\grave{u}'y}$ (3)

In sum, this system allows for consistently (avoiding double-counting, etc.) measuring the direct and indirect social and environmental requirements for the goods and services supplied to the consumers.

A4.3 Data and regionalization method for the construction of the input-output table

The most recent dataset from the Global Trade Analysis Project (GTAP) version 9 with detailed accounts of regional production and consumption, bilateral trade flows, land use, energy flows, and CO2 emissions, all for the base year 2011 was used (Narayanan et al. 2015). The GTAP database is aggregated toward a composite dataset that accounts for the specific regional requirements of the analysis. Regarding the data regionalization and update, the departure matrix of a country, surrounding or neighbouring region with an economy similar to the one under consideration, which in this case is the country table for 2011 of GTAP 9 was first chosen. One of the most popular regionalization methods, variants of the Simple Location Quotient (SLQ) method[2] which has been recently developed and defended as superior to many others including the Flegg's Location Quotient (FLQ) (Tohmo 2004; Flegg and Webber 1997, 2000; Flegg et al. 1995; Flegg and Tohmo 2013; Kowalewski 2012) was followed. These works have shown the advantages of this method (e.g. improving the SLQs –only accounting for the selling sector- and Cross Industry Local Quotient, CILQ –considering the selling and purchasing sector, but useless for the main diagonals). In order to use this method, and regionalize to the delta, the original national table and data of intermediate transactions, the employment and production totals by sector were the main data employed. Then, completing other parts of the table with "real" or specific delta data (e.g. the rows of employment, land use, etc., and columns of household consumption, government, exports, etc.), these "superior" data are added to make the best use of the available local data and avoid possible biases.

A4.4 Peculiarities for the construction of the input-output table of the Volta Delta

The main information that allows doing the regionalization are the District Analytical Reports (by each of the 10 districts, GSS, 2014). In particular, the *"Table 4.4: Employed population 15 years and older by Industry and sex" and "Table 4.3: Employed population 15 years and older by occupation and sex", complemented by other information*[3]. With these tables, for the Volta delta in Ghana, a RAS approach was performed to apportion the employment by category type (lab, mgr, tec, clk, srv, which are the unskilled and skilled categories of GTAP 9, see Appendix 1) and sector (each of the 57 sectors). On the one hand, the employment by district and gender (male/female) for 21 sectors, which were split to 57 (the agricultural sector was disaggregated based on the particular information of the table *"Table 7.1: Households by agricultural activities and locality"* and the agricultural production data (MOFA, 2015); while the rest of the sectors were split in the same proportion than the equivalent split of 21 to 57 at the national level of Ghana, which was given in the labour force survey that the ILO gathered (ILO, 2015). At this national level, the information of the employment by category type (lab, mgr, tec, clk, srv) by each of the 21 sectors exists (ILO, 2015). But for the districts, only the total by category type (lab, mgr, tec, clk, srv) were obtained, not knowing for which of the 21 districts it belongs.

One could split these employments by category type as for the nation (Ghana), but then the employment by each of the 57 sectors already obtained could not be matched. That is why the RAS approach for this 5x57 employment table was needed to match the totals by category

[2]Several studies among the earliest ones identified and defended the Simple Location Quotient method (Schaffer and Chu 1969a, 1969b; Morrison and Smith 1974; Eskelinen and Suorsa 1980; Sawyer and Miller 1983).

[3] "Table 7.1: Households by agricultural activities and locality"
"Table 4.6: Employed population 15 years and older by employment sector and sex"
"Table 4.5: "Employed population 15 years and older by employment status and sex"
"Table 2.1: Population by age, sex and type of locality" (to capture demography)
"Table 4.1: Population 15 years and older by activity status and sex" (to connect the demography with employment)"Table 2.5: Birthplace by duration of residence of migrants" (to capture migration)".

type, and at the same time by sector (already obtained as explained above for the 57 of GTAP). Finally, at the national level, minor corrections were applied to the employment data in order to obtain (as the ratio of the labour rows in GTAP and the employment of people) reasonable wages, when they do not reach a minimum of 100$ per year (e.g. as it occurs with the original data of the wage of unskilled labour in the transport sectors) or exceed the maximum of 200,000$ per year (e.g. as it occurred with the original data of the wage of the managers and professionals in the transport sector and for the technicians and associate professionals in the dwellings sector).

Other key data for the construction of the IO table, in particular the agricultural sector, were the agricultural land uses, production, prices, data of livestock numbers and keepers (MOFA, 2015), and for fisheries, the FAO and Fisheries Report 2012. Then the Social Accounting Matrix (SAM) was obtained from the regionalization of transfers and institutional (government, households, societies) interrelations, both at the national (already in GTAP 9) and delta levels.