Journal of Al-Azhar University Engineering Sector

Vol.16, No. 60, July 2021, 565-578

ENHANCEMENT OF WATER SECURITY BY DECOUPLING WATER USE FROM ECONOMIC DEVELOPMENT IN EGYPT

Rabab Gaber*[1], and M. Nour El-Din[2]

[1] Water Resources Department, Planning sector, Ministry of Water Resources and Irrigation, Giza, Egypt.

[2] Irrigation and Hydraulics Engineering Department, Faculty of Engineering, Ain Shams University, Cairo, Egypt.

*Corresponding Author's E-mail: rabab1403 @hotmail.com

Received: 17 April 2021 Accepted: 28 May 2021

ABSTRACT

Decoupling water use from economic development is a fundamental strategy to improve environmental quality from the source. Decoupling can promote economic growth while reducing water use and water pollution. This paper not only comprehensively considers the impact of economic development on water resource consumption and water pollution, but also studies technological innovation that may contribute to decoupling in the water sector. Decoupling can evaluate the linkage between resource use or environmental impacts with the economy by calculating a specific index. There are three decoupling indices in the literature among them Tapio decoupling index which is used in current paper.

The decoupling index for the water use for agriculture with respect to the agricultural consumption footprint was estimated to indicate relative decoupling. It was found also that the decoupling index for pesticide use and fertilizer use per capita gross agricultural production showed "relative decoupling". It also shows that the dependence of economic development on water resources is gradually decreasing. The government needs to focus on the wastewater treatment, strengthen the awareness regarding water conservation at the same time, and use stepped pricing standards to reasonably control municipal water use.

Keywords: Decoupling; Decoupling analysis; Water consumption; Virtual water; Economic Growth;

تعزيز الأمن المائي من خلال فصل استخدام المياه عن التنمية الاقتصادية في مصر

رباب جابر*، ومحمد نور الدين
إدارة الموارد المائية، قطاع التخطيط ، وزارة الموارد المائية والري ، الجيزة ، مصر.
قسم الرى والهيدروليكا، كلية الهندسة , جامعة عين شمس, القاهرة , مصر.
*البريد الاليكتروني للباحث الرئيسى: rabab1403 @hotmail.com

الملخص العربى:
يعتبر فصل استخدام المياه عن التنمية الاقتصادية استراتيجية أساسية ومهمه لتحسين جودة البيئة مع تعزيز النمو الاقتصادي وتقليل استخدام وتلوث المصادر المائية. هذه الورقة البحثية تتناول بشكل شامل إرتباط وتأثير التنمية الاقتصادية على استهلاك موارد المياه وعلي تلوث المياه وكذلك تدرس وتقدم الإجراءات والحلول التي تساهم في فصل قطاع المياه عن التنمية الإقتصادية. يمكن للفصل أن يقيم إرتباط استخدام الموارد المائية والتأثيرات البيئية بالإقتصاد من خلال حساب مؤشرات معينة، هناك ثلاثة مؤشرات فصل تم طرحهم في أبحاث سابقة من بينها مؤشر فصل Tapio الذي تم استخدامة في هذه الورقة البحثية.

من خلال هذه الورقة تم تقدير مؤشر الفصل لاستخدام المياه في الزراعة فيما يتعلق ببصمة الاستهلاك الزراعي وتبين من النتائج أنه "فصل نسبي" وكذلك تم حساب مؤشر الفصل بين استخدام مبيدات الآفات واستخدام الأسمدة للفرد من إجمالي الإنتاج الزراعي أظهر "فصل نسبي " أيضا وهذا يدل علي أن إعتماد التنمية الاقتصادية على الموارد المائية يتناقص تدريجياً حيث هناك المشاريع الخدمية والسياحية وكذلك الصناعية. تم طرح عده بدائل وحلول لدعم فصل المياه عن الاقتصاد مثال التركيز على معالجة مياه الصرف الصحي، وتعزيز الوعي بشأن الحفاظ على المياه في نفس الوقت، واستخدام معايير تسعير متدرجة للتحكم بشكل معقول في استخدام المياه مع تطبيق طرق الري الحديثة وترشيد استهلاك المياه في قطاع الزراعة.

الكلمات المفتاحية : الفصل، تحليل الفصل،استهلاك الماء، المياه الافتراضية ،النمو الاقتصادي

1. Introduction & Background

1.1 The concept of decoupling

The first use of decoupling concept was in physics, to eliminate the corresponding relationship between two or more physical quantities. Decoupling happened when the returns of one asset class are not in its normal correlation with others. Decoupling takes place when different asset classes that in the normal cases rise and fall together in the same direction start to move in opposite one. Investors usually use a statistical measure known as correlation to determine the relationship between two assets or more. The strength of the correlation between two assets depends on where the metric falls within the range of -1 to +1, where -1 implies that the assets move in the opposite direction, and +1 means that the assets will always move in the same direction. By understanding which assets are correlated, investors create diversified portfolios by allocating investments that are not correlated with each other. This way, when one asset value falls, the other investments in the portfolio don't have to follow the same path.

The term "decoupling" has been used to make a break between "economic goods" and "environmental bads" connection (OECD, 2002). For example, at 2008 , the US financial crisis started and spread to most markets in the world, Since the markets are "coupled" with the U.S. economic growth, any market that moves opposite to the global trajectory is known as a decoupled market or economy. The concept has been applied in the environmental field in evaluating the relationship between environmental stress and economic growth (Zhang, Song, Su, & Sun, 2015). Resource decoupling is the idea that economic growth can be achieved realized without a reciprocal increase in natural resources consumption.

1.2 **Types of decoupling analysis models**

There are different models used to define decoupling among these are OECD decoupling factor model, Tapio elastic analysis (TEA) method, and the IGTX decoupling model have been used to evaluate decoupling trends of economic growth and CO2 emissions in typical developed and developing countries. IGTX is a kind of equation in which, (I) represents environmental pressure; G represents the gross domestic product (GDP); T represents the amount of waste generation; and X represents the discharge rate of waste.

The decoupling elastic analysis method has attracted much attention from scholars (Juknys, 2003). there are two types of decoupling , primary decoupling, between economic growth and natural resources. Secondary decoupling is between natural resources and environmental pollution. Tapio proposed a decoupling model, which improves objectivity and accuracy (Tapio P., 2005). Tapio used his model in analyzing the relationship among economic developments, transportation volume, and greenhouse gas emission in Europe from 1970 to 2001. Other scholar such as Gray used the Tapio decoupling model also to analyze the decoupling relationship among economic growth, transportation volume, and carbon emissions in Scotland (Gray, D; Anable, J; Illingworth, L., 2006).

Decoupling method is a very effective tool to evaluate sustainable development and to provide the policy makers with useful information. In 2011, UNEP developed a model centered on two decoupling mechanisms (UNEP, 2015). First one is ‘Resource Decoupling’ which occurs when resource consumption increases at a slower rate than economic growth, which cause a reduction in relative resource intensity per unit of economic output. The second, ‘Impact Decoupling’ takes place when the environmental impact of economic growth through resource consumption is reduced or eliminated through changed behavior, such as the use of renewable rather than fossil energy sources, as shown in Figure (1).

Decoupling analysis has been widely used in environmental science and energy consumption (Yu Y., 2017) , (Wang Q., Li R., Jiang R., 2016), Decoupling analysis has provided a feasible strategy for integrated water resources management (IWRM) schemes and a practical direction for attaining the sustainable development goals. (Song & Zhang, 2017), (Wang, Hashimoto, Yue, Moriguchi, & Lu, 2013), (Acheampong, Swilling, & Urama, 2016,).

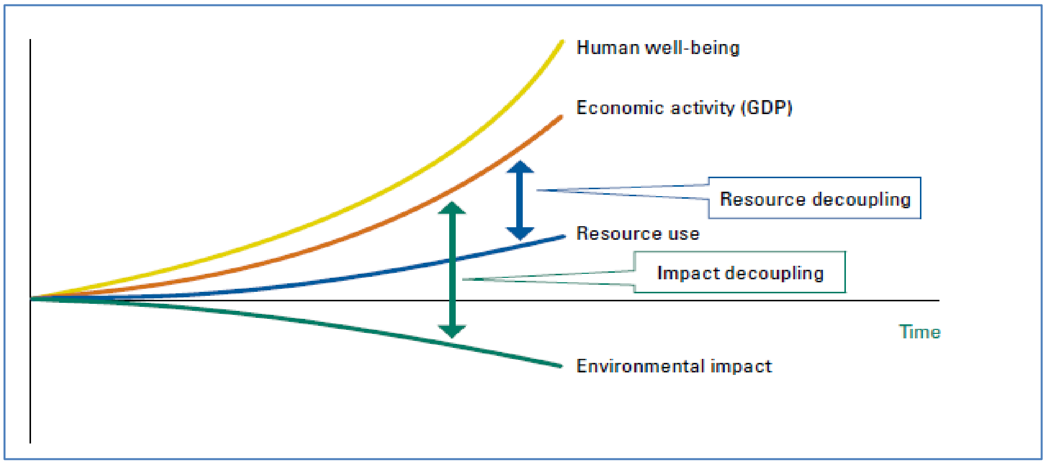

Figure 1: Aspects of Decoupling, *Source: UNEP (2011a)*

2. Application of Water Decoupling Models in Egypt

Previous research developed a water decoupling model, building on the notion that food trade and recycling could be a means of decoupling a nation's water needs from national naturally derived water use (Gilmont M. , 2014). A further iteration takes into account the importance of economic diversification away from agriculture towards higher value sectors, increasing the economic return on national water use, or 'dollar per drop' (Gilmont, 2015).

A water-specific decoupling model presents an opportunity to understand the difference and potential inherent in different economic and technical instruments, by reducing developmental pressure on scarce natural water resources. Decoupling water from economic growth measurements can be divided into three methods which are variable comprehensive analysis method, decoupling index method and elasticity index method.

The most used decoupling analysis approach is the elasticity index method. Scholars (Wang, Q.;Jiang, R.;Li,R., 2018). To overcome the shortcomings of previous attempts to analyze the relationship between economic development and water consumption, this current paper incorporates decoupling analysis with the Tapio decoupling model based on extracting the trend components of water consumption and GDP time series.

In the current paper we started by analyzing the relationship between economic development and water consumption, the Relative growth of Economy, food production, and water consumption data in Egypt from 1910 to 2020 (1965=100% base year) were presented in figure 2.

Four modes of decoupling were observed:

- Economic decoupling :economic diversification reduces correlation between economic and agricultural outputs (total water demands increase decouples from GDP) that is because the GDP depends on the service sector in addition to industry sector.

- Trade based decoupling: total water demands of population increase decouples from available total water resources through trade starting from the 1970s that is because we start to fill the gap by export “virtual water “
- Natural water decoupling : total water resources increase decouples from total renewable water resources increase through drainage water reuse starting from 1980s that is because drainage and treated wastewater reuse and desalination
- Efficiency based decoupling: domestic food production increase decouples from the total water resources increase through irrigation water efficiency increase by irrigation improvement projects and drainage water reuse starting from 1990s

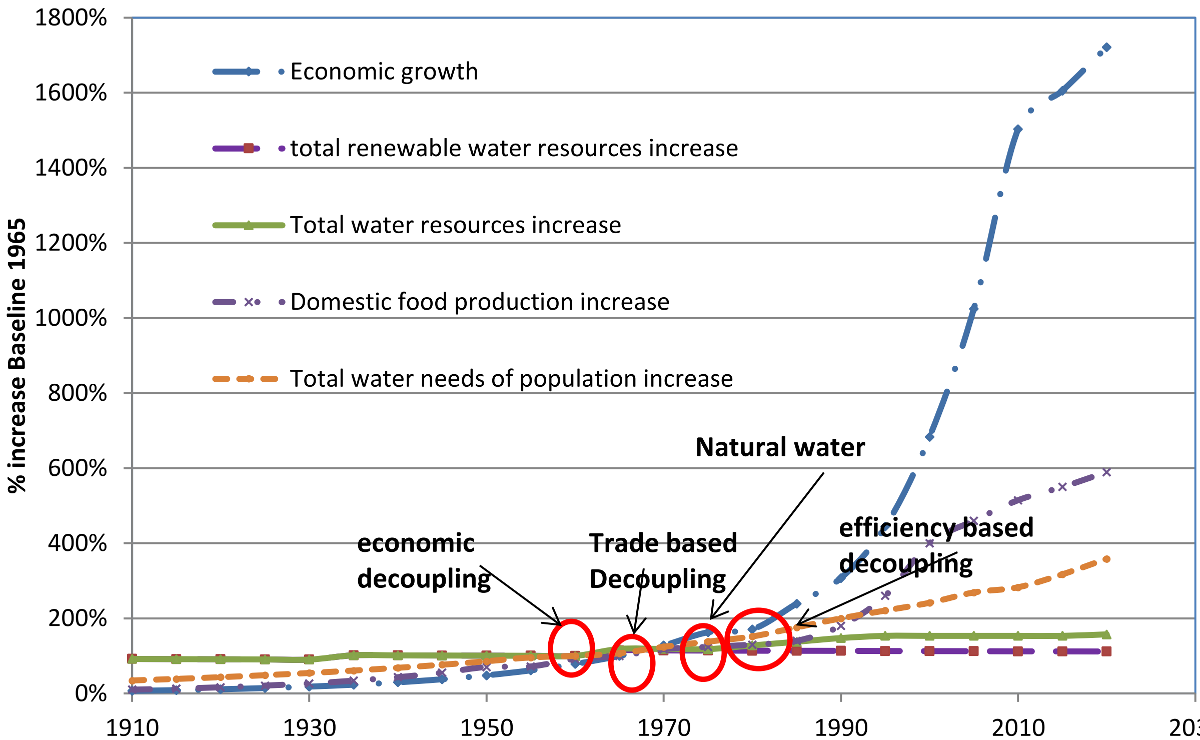

Figure 2: **Relative growth of Economy, food production, and water in Egypt from 1910 to 2020 (1965=base year)**

The decoupling of GDP from environmental impacts due to Egypt consumption was evaluated through the decoupling index (DI). The environmental impacts were quantified by adopting the Life Cycle Assessment LCA-based Consumption Footprint (CF) set of indicators (E.Sanyé, M.Secchi, S.Corrado, A.Beylot, & S.Sala, 2019). The CF adopts the impact categories recommended in the Environmental Footprint (EF) life cycle impact assessment (LCIA) method (EC, 2013).

Resource decoupling has been performed on the country scale to illustrate how the economic development has become independent of the agricultural production and water resources in Egypt starting from 1970s. Today, Egypt’s economy is dominated by services 54% , industry 34.3% with agriculture contributing only 11.7 % of GDP and employing 25.8 % of the labour force as in 2016. Despite agricultural sector contribution is low to overall economic activity; agriculture consumes about 80% of the total annual water resources in Egypt. However this differs from the decoupling between consumption footprint of agricultural production and environmental impacts. The following sections explain the principles of DI and the CF calculation and the evaluation of decoupling index of agricultural environmental impacts with respect to the water consumption footprint will be performed.

2.1 Decoupling index for Egypt

The decoupling can evaluate how resource use or environmental impact is linked to the economy by calculating a specific index. The first is the decoupling factor introduced in OECD (2002), defined by the rate of growth of emissions´ intensity (emissions/GDP), which has clear limitations. Decoupling is only associated to a reduction in emissions' intensity, but that scenario can be with emissions increasing while the economy is expanding and with emissions decreasing but economic activity falling. The second indicator was introduced by Tapio (2005) and is defined as emissions-to-economic activity elasticity (rate of emissions´ change/rate of GDP change). Then the third one of decoupling was introduced by Lu et al (2011) and its formula includes, in addition to GDP growth, the emissions´ intensity decreasing rate.

Those three indices can be compared and, in fact, as shown in Conte Grand (2016), Lu et al (2011) and Tapio (2005) indicators are one a linear transformation of the other. Hence, there is no loss by using one or the other. As proposed by (Tapio P., 2005), the calculation of the elasticity between the changes along time of the two assessed parameters, e.g. transport volume and GDP. This ratio was defined as Decoupling Index (DI) (UNEP, 2011), (E.Sanyé-Mengual, M.Secchi, S.Corrado, A.Beylot, & S.Sala, 2019).

Decoupling Index "DI" is the ratio between the relative variation of environmental impacts (EI) and the relative variation of the economic output, in terms of GDP (Eurostat, 2018), for a defined timeframe as illustrated in Eq.1.

$$DI = \frac{\Delta EI}{\Delta GDP} = \frac{(EI_{t+1} - EI_t)/EI_t}{(GDP_{t+1} - GDP_t)/GDP_t} \qquad \text{Eq.1}$$

Table1. The environmental decoupling classification as adjusted by (Wu, Zhu, & Zhu, 2018)

Environmental Decoupling classification	DI	ΔEI	ΔGDP	Status description
Absolute decoupling	DI < 0	ΔEI<0	ΔGDP>0	The environmental impact decreases while the economic output keeps growing.
Relative decoupling	0<DI<1	ΔEI>0	ΔGDP>0	The environmental impact increases although at a slower pace than the economic output.
Non-decoupling	DI > 1	ΔEI > 0	ΔGDP>0	The environmental impact increases more than the economic growth.
Stagnant	DI≠0	ΔEI<±0	ΔGDP≤0	The economic output remains stable or decreases while the environmental impact shows a small variation, suggesting that the decoupling is linked to the stagnation of the economy.

2.2 Consumption footprint accounting method: how the environmental impacts are assessed(CF)
The Consumption Footprint (CF) (Sala S., (2019)) is the logarithmic mean division index (LMDI) decomposition method. The inventory of pressures for the trade component is compiled either with a bottom-up approach (process-based LCA of representative traded goods) or a top-down approach (input-output-based LCA) LCA-based set of indicators aiming at tracking the overall environmental impacts of consumption. The CF takes into account both the impacts associated with domestic of activities (Domestic footprint) and the ones associated with trade (Import and Export footprints).The CF is calculated as

Consumption footprint=Import footprint +Domestic footprint-Export footprint

Domestic agricultural products Footprint (DF), agricultural imports, agricultural exports and agricultural consumption footprint CF are illustrated in (Fig. 3) quantifies impacts stemming from both agricultural production and consumption activities taking place within the country. This means that environmental impacts occurring in the country due to those of the agricultural activities were considered as 'domestic' component. The domestic food production is decoupled from water use for agriculture as shown in figure 3.

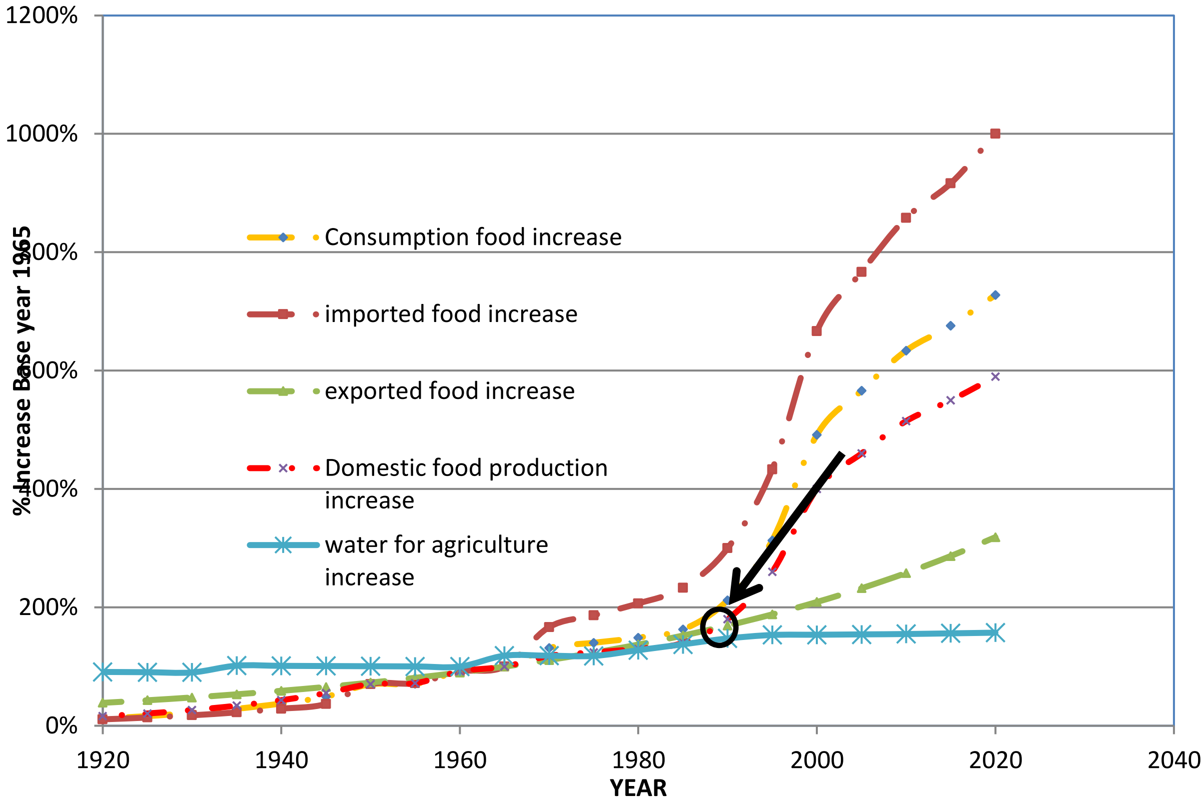

Figure 3: Agricultural production, consumption and trade decoupling for Egypt

We can see from the figure that up to 1970s the Consumption food increasing was less than the water for agriculture, starting from the 1970s, the consumption food increase has decoupled from the water use of agriculture because of the imported food increase by virtual water. The decoupling index of the agricultural water uses with respect to the agricultural consumption footprint varies from 0.00001 to 0.02 indicate relative decoupling as shown in Figure "4" which means the consumption food increases, and the water for agriculture also increase but not in the same rate as water for agriculture almost seems to be constant for the last decades.

As per trading economic site for Egypt, The virtual water for agricultural imports is 50.6 BCM, whereas the virtual water for agricultural exports is 7.4BCM, and the allocated water for agriculture for domestic production is 61.8 BCM in 2020.

Table 2: decoupling index of water for agriculture w.r.t. consumption food calculation data

year	water for agriculture BCM	Consumption food Billion US$	Decoupling Index of water consumption
1970	46.20	7.63	0.000084
1975	46.22	8.15	0.020154
1980	50.05	8.65	0.011185
1985	53.90	9.45	0.002622
1990	57.75	12.33	0.000184
1995	58.52	18.20	0.000034

2000	58.91	28.56	0.000052
2005	59.29	32.90	0.000100
2010	60.06	36.83	0.000142
2015	60.83	39.26	0.000106
2020	61.60	42.28	0.000559

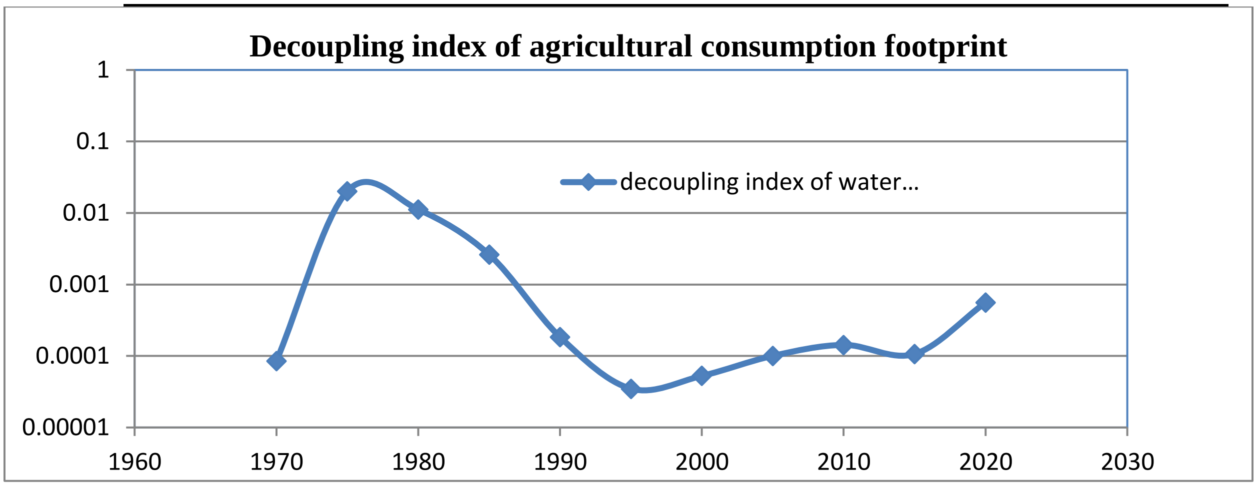

Figure 4: the decoupling index of water use for agricultural with respect to the agricultural GDP

Table 3: Distribution of the virtual water of the agricultural exports in Egypt during 2020 https://tradingeconomics.com/egypt/exports)

CROP	Qty million ton	virtual water m^3/ton	virtual water BCM
Citrus	1.8	2000	3.6
potatoes	0.68	500	0.34
onion	0.421	400	0.1684
beet	0.345	300	0.1035
grape	0.2	869	0.1738
sweet potato	0.1	500	0.05
mango	0.05	1820	0.091
garlic	0.035	400	0.014
bean	0.023	430	0.00989
guava	0.009	630	0.00567
bell pepper	0.005	400	0.002

Sugar cane	0.33	1500	0.495
Rice	0.75	3000	2.25
Tomatoes	0.143	600	0.0858
green bean	0.025	450	0.01125
Total	**4.916**		**7.40031**

From table 3, the calculation showed that the Virtual water of the agricultural exports in Egypt during 2020 is 7.4 BCM that is equivalent to 2.2 Billion US$.

Table 4: Distribution of the virtual water of the agricultural imports in Egypt during 2020 https://tradingeconomics.com/Egypt/imports, 2020)

CROP	Qty million ton	virtual water m^3/ton	virtual water BCM
Wheat	13	1350	17.55
Maize	10	1700	17
soya bean	4.7	2145	10.0815
Cotton	0.087	10000	0.87
milk products	0.23	900	0.207
Poultry	0.15	2800	0.42
Meat beef	0.28	16000	4.48
Total	**28.447**		**50.6085**

From table 4, the calculation showed that the Virtual water of the agricultural imports in Egypt during 2020 is 50.6 BCM that is equivalent to 15 Billion US$.

2.3 Decoupling of agricultural pollution from agricultural economy:

The development of the agricultural economy in Egypt has brought the agricultural pollution, and agricultural pollution has restrained the growth of the agricultural economy and endangered environment and public health due to excessive use of fertilizers and pesticides. The relationship between the agricultural economy and agricultural pollution is studied in the current paper by using decoupling index method and verified by the data of 1970-2020. The decoupling index for pesticide use and per capita gross agricultural production showed "relative decoupling". From 1982-2020, the value of it decreased from 0.07 to 0.001 and its decoupling state gradually transited to **relative decoupling**.

Chemical fertilizer use in Egypt has increased significantly since the construction of the Aswan High Dam. Increased applications of chemical fertilizers in irrigated lands are likely to create nonpoint contamination sources of chemical fertilizer species, chemical fertilizer showed a "relative decoupling".

The environmental impact increases slower than the economic output. The value of decoupling index decreased from 0.08 to 0.001, while its state gradually changed to **relative strong decoupling**.

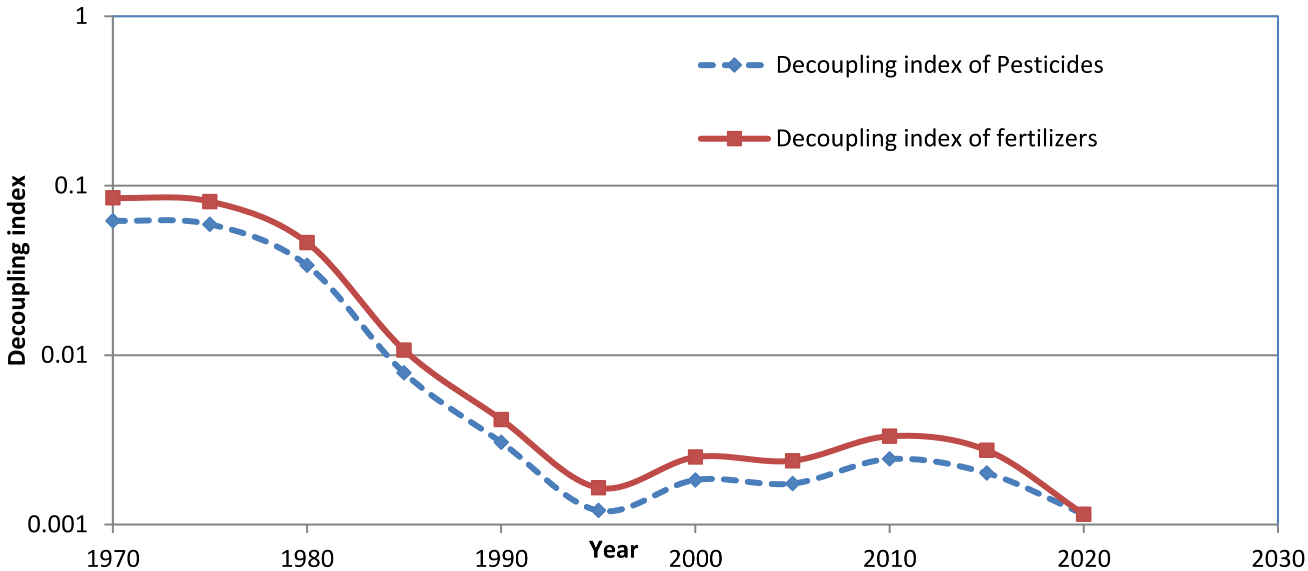

Figure 5: the decoupling index of pesticides and fertilizer use with respect to the agricultural GDP

Table 5: decoupling indices of fertilizers and pesticides w.r.t. domestic food production calculation data

Year	Domestic food production billion US$	Pesticides ton	Decoupling index of Pesticides	Fertilizers million ton	Decoupling index of fertilizers
1970	6.2	10600	0.06214	3.33	0.08474
1975	6.5	11766	0.05913	3.83	0.08064
1980	7.0	13060	0.03384	4.41	0.04615
1985	9.0	14497	0.00785	5.07	0.01071
1990	13.0	16092	0.00305	5.83	0.00416
1995	20.0	17862	0.00121	6.70	0.00164
2000	23.0	19826	0.00183	7.71	0.00250
2005	25.7	22007	0.00174	8.87	0.00238
2010	27.5	24428	0.00243	10.20	0.00332

2015	29.5	27115	0.00201	11.73	0.00274
2020	6.2	30098	0.00115	13.49	0.00115

3. Summary Results, Conclusions & Recommendation

From previous section "2" in which we applied the Decoupling models in Egypt and calculated the Decoupling index for Egypt using the 2020 data, and by analyzing the relationship between economic development and water consumption, as well as studying the possibilities to improve water security by decoupling. We can find that the Relative growth of Economy, food production, and water consumption data in Egypt from 1910 to 2020 (1965=100% base year) were presented and four modes of decoupling were observed. First one is the economic decoupling, total water demands increase decouples from GDP that is because the GDP depends on the service sector in addition to industry sector. Second, for trade based decoupling, total water demands of population increase decouples from available total water resources through trade starting from the 1970s as we start to fill the gap by export “virtual water “. Third, the total water resources increase decouples from total renewable water through water reuse and desalination. Fourth food production increase decouples from the total water resources increase through irrigation water efficiency increase by irrigation improvement projects and drainage water reuse starting from 1990s.

The agricultural consumption footprint is relatively decoupled from per capita gross agricultural production and the decoupling index is varied from 0.00001 to 0.01, this means that there is a need for measures to be taken as efficient irrigation delivery systems, rehabilitation of infrastructures, good irrigation water quality, crop varieties with reduced Water requirements, and wastewater reuses to enhance the decoupling in water sector.

In the same context the pesticide use was slightly increasing and the per capita gross agricultural production was increasing in most years, which indirectly indicated that the growth in the agricultural economy has an effect on agricultural pollution; it was found that the decoupling index for pesticide use and per capita gross agricultural production From 1982-2020, the value of it decreased from 0.07 to 0.001 and its decoupling state gradually transited to relative decoupling.

The decoupling analysis is an effective tool to examine the measures of the National Water Resources Plan for Egypt "NWRP" with respect to the water resources used, agricultural consumption footprint, the domestic water use and the resulted pollution. The decoupling analysis can test and evaluate the NWRP measures to enhance the water security of Egypt to can face the water challenges such as population increasing, climate change and other water challenges.

From the Summary results above, we can find that the decoupling is an effective tool to examine progress of the measures of the national water resources plan with respect to the water resources used, agricultural consumption footprint, the domestic water use and the resulted pollution.

As Egypt is looking forward to enhance the water resources uses by enhancement actions and measures which included in the National Water Resource Plan for Egypt, So we recommended using the decoupling analysis to test and evaluate the NWRP measures to enhance the water security of Egypt which is very difficult to keep as a result of many challenges such as rabidly increasing of population, climate change and its effect on the agriculture water consumption, available investment for rehabilitation, operation& maintenance for the water resources network.

Technological innovation and solutions with the potential to contribute to decoupling for the agricultural, industry and municipal water-supply sectors can be taken. **In Agricultural sector,** Efficient irrigation delivery systems, rehabilitation of infrastructures , good irrigation water quality, Crop varieties with reduced transpiration requirements, wastewater reuses are some actions which has to be taken to enhance the decoupling in water sector. In **Municipal sector,** Leakage reduction and non-revenue water in domestic supply systems, improve the efficiency of household water use; reduce the network leakage by rehabilitation and operation and maintenance. On the level of the house, using the water sensors especially in the public places is very important. Enhance wastewater treatment performance and safe disposal. Increase the no of wastewater treatment plant especially in the rural area. **In Industrial sector,** Optimization of the heating and cooling needs: use of the same water for multiple cooling or heating purposes depending on the temperature needs, Enhancing water quality: in order to avoid losses of heat transfer. Moreover, it is possible to reuse the same water in an increased number of cycles such as multiple-pass cooling/heating instead of single-pass systems. Pressurized cleaning: by applying a pressurized stream of water, or an air-water mixture, flowing at a high- velocity, achieving cleaning with reduced water flows.

References

1. Acheampong, E., Swilling, M., & Urama, K. (2016,). Developing a framework for supporting the implementation of Integrated Water Resources Management IWRM with Decoupling Strategy. Water Policy, 18, 1317-1333.

2. E.Sanyé, M., M.Secchi, S.Corrado, A.Beylot, & S.Sala. (2019). Assessing the decoupling of economic growth from environmental impacts in the European Union: A consumption-based approach. Journal of Cleaner Production, volume 236, 117535, ELSEVIER.

3. EC. (2013). Commission Recommendation of 9 April 2013 on the Use of Common Methods to Measure and Communicate the Life Cycle Environmental Performance of Products and Organisations 2013/179/EU. . Brussels: European Community.

4. Eurostat. (2018). Gross domestic product - chain linked volumes (2010), . http://ec.europa.eu/eurostat/data/database (2018).

5. Gilmont, M. (2014). Decoupling dependence on natural water: reflexivity in the regulation and allocation of water in Israel. Water Policy,16(1), p79–p101.

6. Gilmont. (2015). Analysing the economic development impact of semi-arid lands, and mitigation by food-trade water resource decoupling (Working Paper). London: Overseas Development Institute.

7. Gray, D; Anable, J; Illingworth, L. (2006). Decoupling the link between economic growth, transport growth and carbon emissions in Scotland. Scotland: Robert Gordon University;.

8. Juknys, R. (2003). Transition Period in Lithuania-DoWe Move to Sustainability Environmental Research. . Eng. Manag.

9. OECD. (2002). Indicators to Measure Decoupling of Environmental Pressure from Economic Growth. http://www.oecd.org/environment/indicators-modelling-outlooks/1933638.pdf.

10. Song, Y., & Zhang, M. (2017). Using a new Decoupling indicator (ZM Decoupling Indicator) to study the relationship between the economic growth and energy consumption in China. Natural Hazards,88,1013-1022.

11. Sorrell, S., Lehtonen, M., Stapleton, L., Pujol, J., & Champion, T. (2012). Decoupling of Road Freight Energy Use from Economic Growth in the United Kingdom. Energy Policy 2012, 41, 84–97.

12. Tapio P. (2005). Toards a Theory of Decoupling: Degree of Decoupling in the EU and the case of Road Traffic in Finnlandbetween 1970 and 2001 . Transperancy Policy 12, 137-152.

13. UNEP. (2011). Decoupling natural resource use and environmental impacts from economic growth. A Report of the Working Group on Decoupling to the International Resource Panel. Available at:. http://www.unep.org/resourcepanel/decoupling/files/pdf/.

14. UNEP. (2015). Measuring water use in a green economy. A Report of the Working Group on Water Efficiency to the International Resource Panel. Available at:. http://www.unep.org/resourcepanel/Portals/.

15. Vehmas J., Kaivo-Oja, Luukkanen J. (2003). Global Trends of Linking Environmental Stress and Economic Growth. Turku, Finnland: Finnland Future Research Center, pp.6-9.

16. Wang, H., Hashimoto, S., Yue, Q., Moriguchi, Y., & Lu, Z. (2013). Decoupling Analysis of Four Selected Countries. Ind. Ecoli 17, 618-629.

17. Wang Q., Li R., Jiang R. (2016). Decoupling and Decomposition analysis of Carbon Emission from industry A case study from China. Sustainability , 8, 1059.

18. Wang, Q.;Jiang,R.;Li,R,. (2018). Toward the coordinated Sustainable Development of Urban Water Resources Use and Economic Growth: An . Sustainability,10,1323.

19. Yu Y., Z. L. (2017). Decoupling Environmental Pressure from Economic Growth on City Level : The case study of Chongqing in China. Ecol. Indic. 75,27-35.