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Charakterystyka zrównoważenia rozwoju biogospodarki w Polsce - wymiar ekologiczny

Characteristics of sustainable development of bioeconomy in Poland - ecological dimension

Synopsis. Celem opracowania było określenie, czy istnieją w Polsce możliwości rozwoju zrównoważonej biogospodarki bez narażania się na przekroczenie granic ekologicznych. Do oceny wykorzystano zaproponowane przez Global Footprint Network wskaźniki: biopojemności i śladu gruntowego. Przeprowadzono analizę i ocenę kształtowania się biopojemności i śladu gruntowego oraz wielkości eksploatacji biopojemności w latach 1961-2018. Badane wskaźniki przedstawiono na tle Niemiec i różnych regionów Europy. Na podstawie uzyskanych wyników określono perspektywy rozwojowe silnie zrównoważonej biogospodarki w Polsce. Przeprowadzone badania wykazały, że eksploatacja biopojemności w 2018 r. wynosiła 93% i była bliska gruntowej bariery ekologicznej. Oznacza to, że ekologiczny potencjał zwiększenia produkcji biomasy w Polsce jest mały. Większe możliwości rozwoju biogospodarki z ekologicznego punktu widzenia istnieją w całym regionie Europy Wschodniej i Północnej.

Słowa kluczowe: biogospodarka, rozwój zrównoważony, granice ekologiczne, biopojemność, ślad gruntowy

Abstract. The aim of the study was to determine whether there are opportunities for the development of a sustainable bioeconomy in Poland without the risk of crossing ecological boundaries. The following indicators, proposed by the Global Footprint Network, were used for the assessment: biocapacity and land footprint. An analysis and assessment of the development of biocapacity and land footprint as well as the intensity of biocapacity exploitation in the years 1961-2018 was carried out. The studied indicators are presented against the background of Germany and various other regions of Europe. On the basis of the obtained results, development prospects for a highly sustainable bioeconomy in Poland were determined. The conducted research showed that the exploitation of biocapacity in 2018 amounted to 93% and was close to the ground ecological barrier. This means that the ecological potential for increasing biomass production in Poland is minor. Greater opportunities for the development of the bioeconomy from an ecological point of view exist throughout the region of Eastern and Northern Europe

Key words: bioeconomy, sustainable development, ecological boundaries, biocapacity, land footprint

JEL Classification: O13, Q15, Q56, Q57

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Wprowadzenie

Zrównoważony rozwój został zdefiniowany w 1987 r. przez Światową Komisję G. Brundtland do spraw Środowiska i Rozwoju. W opublikowanym raporcie „Nasza wspólna przyszłość" zrównoważony rozwój został określony jako taki, w którym potrzeby obecnego pokolenia mają być zaspakajane bez uszczerbku dla możliwości spełnienia potrzeb przyszłych pokoleń (WCED, 1987). Celem koncepcji było zapewnienie wzrostu gospodarczego przy jednoczesnej ochronie równowagi społecznej i środowiskowej (Lozano, 2008). Koncepcja zrównoważonego rozwoju była definiowana i interpretowana na wiele różnych sposobów. Mimo, że przesłanie koncepcji było zrozumiałe, to interpretacje i zdefiniowanie prowadziły do szeregu dyskusji, a tym samym stopniowego rozszerzania zakresu problematyki dotyczącej tej idei.

W ostatnich latach dostrzega się zmianę postrzegania rozwoju społeczno-gospodarczego. Rosnąca populacja ludności i konieczność zapewnienia bezpieczeństwa żywnościowego, zrównoważona konsumpcja i produkcja, zachodzące zmiany klimatu oraz presja na ochronę środowiska to wyzwania, które skłaniają do wprowadzania nowych koncepcji i form zrównoważonego rozwoju. Wśród tych koncepcji jest idea biogospodarki.

Biogospodarka jest wiązana intencjonalnie z międzynarodowym programem na rzecz zrównoważonego rozwoju. Zgodnie z deklaracją z Rio w sprawie środowiska i rozwoju, zrównoważony rozwój powinien zaspakajać potrzeby obecnego pokolenia bez uszczerbku dla możliwości zaspokajania potrzeb przyszłych pokoleń (ONZ, 1992). Definicja ta miała charakter aspiracyjny. Zmieniła ten fakt Agenda ONZ 2030 z listą 17 Celów Zrównoważonego Rozwoju (SDG) (UN SDSN, 2015), które stanowią globalne działanie normatywne dążące do osiągania sprawiedliwego, inkluzywnego, prosperującego wzrostu w granicach naszej planety (Costanza i in., 2016). Deklaratywnie, biogospodarka powinna znacząco przyczynić się zwłaszcza do realizacji SDG 2 (Zero głodu), SDG 12 (Zrównoważona konsumpcja i produkcja) oraz SDG 13 (Działania na rzecz klimatu) (Giuntoli i in., 2020).

Badania i analizy status quo i perspektyw rozwoju biogospodarki doprowadziły do wniosku, iż biogospodarka typowo wiąże się ze słabym zrównoważeniem i opowiada się za wysoką substytucyjnością kapitału naturalnego (naturalnych zasobów) do kapitału antropogenicznego (postępu technologicznego w pozyskiwaniu zasobów) (Loiseau i in., 2016). Także z innych prac wynika, że biogospodarka sama w sobie nie może być uznana za zrównoważoną (Székács, 2017). Niekiedy uważa się, że biogospodarka, gospodarka cyrkulacyjna oraz rozwój zrównoważony to trzy różne, ale pokrywające się trendy w łagodzeniu antropogenicznych wpływów na środowisko (De Oliviera i in., 2018). To w oczywisty sposób mogłoby się przyczynić do problemów w realizacji celów zrównoważonego rozwoju, w tym zwłaszcza celów ekologicznych i wiele strategicznych założeń leżących u podstaw strategii rozwoju biogospodarki musiałoby ulec pewnym rewizjom. Przed ich dokonaniem warto rozważyć jednak rozwój biogospodarki według kryteriów silnego zrównoważenia.

W obliczu poważnych zagrożeń i wyzwań (rosnąca liczba ludności, zmiana klimatu i degradacja gleby) opracowanie stanowi istotny wkład w badania dotyczące silnego zrównoważenia biogospodarki, która odgrywa znaczącą rolę w dążeniu do osiągnięcia celów zrównoważonego rozwoju. Celem opracowania było określenie czy istnieją w Polsce możliwości rozwoju zrównoważonej biogospodarki bez narażania się na przekroczenie granic ekologicznych. Ponieważ rozwój biogospodarki wiąże się z zaspokajaniem popytu i podaży na biosurowce, aby przedstawić jej zrównoważony rozwój wykorzystano zaproponowane przez Global Footprint Network wskaźniki: biopojemności i śladu gruntowego. Tak postawione zdanie badawcze znalazło odzwierciedlenie w konstrukcji pracy. W przeglądzie literatury zaprezentowano istotę słabego i silnego zrównoważenia rozwoju i znaczenie biogospodarki oraz charakterystykę metody badawczej wraz ze źródłem danych. Następnie przeprowadzono analizę i ocenę uzyskanych wyników co pozwoliło wskazać możliwości rozwoju silnie zrównoważonej biogospodarki w Polsce. Badane wskaźniki przedstawiono na tle Niemiec i różnych regionów Europy.

Przegląd literatury

Na przestrzeni lat debatę nad zrównoważonym rozwojem zdominowały dwa konkurujące ze sobą podejścia, silnego i słabego zrównoważenia. Większość uczonych zgadza się z podziałem kapitału na naturalny, rzeczowy (wytworzony), ludzki i społeczny (Deng, 2007; Ekins i in., 2008). Każdy z nich pełni swoje funkcje w formowaniu poglądu na społeczno-środowiskowe otoczenie, a zrozumienie relacji między nimi ma istotny wpływ na sposób interpretacji i oceny zrównoważonego rozwoju.

Słabe zrównoważenie opiera się na ekonomii dobrobytu i jest interpretowane jako zasada wzrostu gospodarczego na przestrzeni jednego lub kilku pokoleń (Hartwick, 1990; Solow, 1993). Podstawą tego podejścia było założenie, że kapitał naturalny i kapitał wytworzony są doskonale zastępowalne, a do ochrony środowiska niezbędny jest wzrost gospodarczy, przy którym innowacje technologiczne rozwiążą wszystkie problemy środowiskowe (Loiseau i in., 2016; Liobikiene i in., 2019). Tym samym kapitał wytworzony stał się ważniejszy od kapitału naturalnego (Davies, 2013). Według zasady słabego zrównoważenia konieczne jest aby całkowita ilość kapitału była zachowana bez zwracania uwagi na jego strukturę (Wilson i Wu, 2017). Stwierdza się także, że kapitał naturalny nie jest ograniczony barierami środowiskowymi, a jego degradacja jest odwracalna (Pelenc i Ballet, 2015). Taka orientacja jest charakterystyczna dla antropocentrycznego pojmowania zrównoważonego rozwoju.

Silne zrównoważenie to skoncentrowany na środowisku pogląd, który podkreśla znaczenie i niezastąpioną rolę kapitału naturalnego w produkcji i konsumpcji. Koncepcja silnego zrównoważenia zasadza się na ekocentryzmie, przyjmując, że substytucyjność zasobów naturalnych jest ograniczona (Lorek i Spangenberg, 2014). Oznacza to, że pewne działania człowieka mogą pociągać za sobą nieodwracalne konsekwencje, a ochrona środowiska jest niezbędna dla wzrostu gospodarczego (Mancebo, 2013). Zasada silnego zrównoważenia wymaga zwiększenia ogólnej ilości kapitału oraz zachowania racjonalnej struktury kapitału i nieprzekraczania progów ekologicznych (Liobikiene i in., 2019; Rockström i in., 2009).

Wybór między słabą a silną zasadą zrównoważonego rozwoju jest trudny. Skrajne stanowiska rzadko znajdują możliwość praktycznego zastosowania w czystej postaci. Racjonalny wybór leży w przestrzeni między słabym i silnym zrównoważeniem.

Biogospodarka, zrównoważona i cyrkulacyjna (Brenne, 2022; Holden, 2022), ma odegrać wielką rolę w transformacji systemu ekonomicznego, przyczyniając się do dekarbonizacji gospodarek oraz zmniejszenia niedoborów surowców nieodnawialnych. W UE biogospodarka postrzegana jest jako główny element w realizacji Europejskiego Zielonego Ładu oraz różnorodności regionalnej. Aby mogła się do tego przyczynić, należy zadbać o jej zrównoważony rozwój (Brenne, 2022). Zrównoważenie rozwoju biogospodarki zostało omówione dość kompleksowo (D'Amato, 2019; D'Amato, 2020; Giuntoli i in., 2020; Koukios i in., 2018; Liobikiene i in., 2019; Loiseau i in., 2016; Ramcilovic-Suominen i Pülzl, 2018).

Żywe zainteresowanie biogospodarką zaowocowało opracowaniem licznych definicji tego pojęcia. Problemem jest zakres tego pojęcia, które jest uzależnione od przyjętego podejścia: zasobowego (produkcja bazująca na zasobach biologicznych), czy procesowego (wykorzystanie biotechnologii). Poszczególne definicje akcentują różne aspekty i priorytety technologiczno-ekonomiczne czy społeczne i nawiązują do różnych uwarunkowań i koncepcji rozwojowych (Adamowicz, 2017).

Jedną z istotnych definicji przedstawiła Organizacja Współpracy Gospodarczej i Rozwoju (OECD) według której, biogospodarka to działalność polegająca na zastosowaniu biotechnologii, bioprocesów i bioproduktów w celu wytworzenia określonych dóbr i usług (OECD, 2009). Podejście zorientowane na biotechnologię znalazło także wyraz w przyjętej przez Komisję Europejską strategii „Innowacje na rzecz zrównoważonego wzrostu: biogospodarka dla Europy" (EC, 2012). Badania naukowe koncentrowały się na technologiczno- produkcyjnych aspektach biogospodarki (Maina i in. 2017; Pellis i in. 2018; Scheiterle i in., 2018). Jednak Gołębiewski i in. (2015) zauważyli, że podejście zorientowane na biotechnologię i wspieranie rozwoju działalności gospodarczej związanej z biozasobami nie wystarcza do realizacji strategii biogospodarki na rzecz zrównoważonego rozwoju. W literaturze autorzy (Cristoból i in., 2016; Juerges i Hansjürgens, 2018; Scarlat i in., 2015) stwierdzają, że podstawową zasadą zrównoważonej biogospodarki jest zrównoważone wykorzystanie biozasobów. Zdaniem Ott (2003) i Liu (2009) w dążeniu do wzrostu gospodarczego i dobrobytu przy realizacji strategii biogospodarki, koniecznym jest aby biozasoby (potencjał biomasy) nie zostały wyczerpane. Ponadto oceniając potencjał biomasy, należy wziąć pod uwagę ograniczenia ekologiczne i granice planetarne. Takie podejście będzie zgodne z silnym zrównoważeniem rozwoju. Badań w tym zakresie w ostatnim czasie przybywa (Brizga i in., 2019; Bruckner i in., 2019; Egenolf i Bringezu, 2019; Hubacek, Feng, 2016; Liobikiene i in., 2019; Liobikiene i in., 2020; O'Brien i in., 2015).

Skorelowanie pojęcia zrównoważonego rozwoju z biogospodarką i jej silnym zrównoważnieniem skłoniło do wdrażania wskaźników, które umożliwiają określenie dostępnych ilości zasobów biologicznych, ich rozmieszczenie przestrzenne i dostępność w czasie w celu zrównoważonego i efektywnego wykorzystania zasobów bez przekraczania granic ekologicznych środowiska.

Większość badań nad wskaźnikami oceny biogospodarki w wymiarze ekologicznym opierała się na słabym podejściu do zrównoważonego rozwoju, w którym uwzględniono jedynie wpływ wdrażania biogospodarki na środowisko (Budziński i in. 2017; Cristóbal i in., 2016) oraz zużycie i potencjał biomasy (Scarlat i in., 2015; Woźniak i Twardowski, 2018).

Istotą twardego zrównoważenia jest dążenie, aby nie dopuścić do przekroczenia granic planetarnych lub progów ekologicznych, co w następstwie przyniosłoby dalszą degradację biosfery (Rockström i in., 2009). Do opisu twardego rozwoju biogospodarki próbuje się stosować pojęcia biopojemności i śladów, np. gruntowego, azotowego, fosforowego, czy wodnego (Bruckner i in., 2019; Egenolf i Bringezu, 2019; O'Brien i in., 2015). Biopojemność definiowana jest jako zdolność ekosystemów do: produkcji surowców biologicznych, świadczenia usług środowiskowych, ochrony klimatu oraz absorbowania odpadów, przy obecnych systemach gospodarowania i aktualnym poziomie technologii przetwarzania biosurowców (Global Footprint Network, 2023; Wackernagel i in., 2015). Natomiast pod pojęciem śladu gruntowego rozumie się presję człowieka na środowisko, mierzoną ilością ziemi niezbędnej do zaspokojenia potrzeb żywnościowych, surowcowych oraz zapotrzebowania na energię (Arto i in., 2012; Bruckner i in., 2019; Global Footprint Network, 2023; O'Brien i in., 2015). Pojęcia biopojemności i śladu są zdefiniowane globalnie, ale mogą być transponowane do skali regionalnej czy poszczególnych krajów. W takim przypadku wskazują, czy przekroczone zostały progi ekologiczne. Oba wskaźniki wyrażane są w hektarach globalnych. Te ważone produktywnością biologicznie produktywne hektary umożliwiają badaczom przedstawienie zarówno biopojemności Ziemi lub regionu, jak i zapotrzebowania na biopojemność (ślad ekologiczny). Hektar globalny to hektar biologicznie produktywny o średniej światowej produktywności biologicznej dla danego roku (Global Footprint Network, 2023). Hektary globalne są przydatne, ponieważ różne rodzaje gruntów mają różną produktywność. Na przykład globalny hektar pól uprawnych zajmowałby mniejszy obszar fizyczny niż znacznie mniej produktywne biologicznie pastwiska, ponieważ do zapewnienia takiej samej zdolności biologicznej jak jeden hektar pól uprawnych potrzeba więcej pastwisk. Ponieważ produktywność świata zmienia się nieznacznie z roku na rok, wartość globalnego hektara również może się nieznacznie zmieniać w poszczególnych latach.

Porównanie biopojemności ze śladem gruntowym pozwala ocenić przestrzeganie przez ludzkość zasad trwale zrównoważonego rozwoju. Ponadto, takie porównanie pomaga określić najbardziej odpowiednie interwencje polityczne dla stworzenia biogospodarki, która respektuje wszystkie środowiskowe ograniczenia i jest zrównoważona pod względem społecznym i ekonomicznym. Biopojemność powinna być zawsze większa od śladu gruntowego, jeśli ma nie dochodzić do wyczerpywania biozasobów, nadmiernego obciążenia środowiska, a nawet jego degradacji. Im różnica pomiędzy tymi wartościami jest większa, tym lepsze jest zrównoważenie ekologiczne. Jeśli biopojemność jest zbliżona do śladu, to rozwój jest słabo zrównoważony, co oznacza, że produkcja nie powinna być intensyfikowana. Najgorszą z możliwych sytuacji jest, gdy biopojemność jest mniejsza od śladu. Oznacza to, że w skali globalnej przekroczona została granica planetarna, co zagraża integralności biosystemów, ekosystemów i pogarsza generalne i szczegółowe perspektywy rozwojowe (Nykvist i in., 2013; O'Brien i in., 2015). Innymi słowy, im większa eksploatacja biopojemności czyli stosunek śladu gruntowego do biopojemności, tym mniej zrównoważony rozwój. Eksploatacja biopojemności pokazuje, jak wielkie są możliwości zwiększenia śladu gruntowego bez narażenia się na przekroczenie granic ekologicznych.

Koncepcja silnego zrównoważenia zmierza więc w kierunku zrozumienia planetarnych granic oraz progów ekologicznych rozwoju biogospodarki (Costanza i in., 2016; Liobikiene i in., 2019; Liobikiene i in., 2020; Rockström i in., 2009), co zapisane zostało jako jeden z trzech obszarów działań w znowelizowanej unijnej strategii biogospodarki (Brenne, 2022; EC, 2022; EU, 2018). Zidentyfikowano dziewięć "planetarnych systemów podtrzymywania życia", które regulują stabilność i odporność systemu ziemskiego, a zatem są uważane za kluczowe dla przetrwania człowieka, określane jako "granice planetarne" (Rockström i in., 2009; Rockström i in., 2018; Steffen i in., 2015). Dziewięć granic planetarnych to: zmiana klimatu, zmiana integralności biosfery (napędzana przez utratę różnorodności biologicznej), zubożenie ozonu w stratosferze, zakwaszenie oceanów, przepływy biogeochemiczne (zakłócenia w cyklach fosforu i azotu), zmiany systemu lądowego, wykorzystanie wody słodkiej, obciążenie aerozolem atmosferycznym oraz wprowadzenie nowych związków mogących zakłócać biofizyczne funkcjonowanie ekosystemów (np. pierwiastki radioaktywne) (EEA, 2020). Granice planetarne proponują ostrożnościowe granice ilościowe, określane jako limity, w ramach których ludzkość może nadal się rozwijać i kwitnąć, określane również jako "bezpieczna przestrzeń operacyjna". Sugerują one, że ich przekroczenie zwiększa ryzyko wywołania gwałtownych lub nieodwracalnych zmian środowiskowych na dużą skalę, które mogłyby zmienić system ziemski w sposób szkodliwy lub katastrofalny dla rozwoju ludzkości.

Dane i metody

W badaniach wykorzystano obliczone dla Polski biopojemności i ślady gruntowe za lata 1961-2018, pochodzące z bazy danych Global Footprint Network (Global Footprint Network, 2023). Ślad gruntowy uwzględniał grunty: zurbanizowane, orne, pod lasami, wodami oraz użytkami zielonymi (Global Footprint Network, 2023). Oba wskaźniki były wyrażone w hektarach globalnych i znormalizowane per capita. Dzięki temu dane dla Polski są porównywalne z danymi dla innych regionów lub krajów, co umożliwiło szerszą dyskusję uzyskanych wyników. W śladzie gruntowym nie uwzględniono śladu węgla (emisji gazów cieplarnianych), który zwiększałby ślad gruntowy niemal dwukrotnie. W wykorzystanej bazie danych nie ma danych na temat wielkości emisji gazów cieplarnianych. Dane te można pozyskać z baz Eurostatu i FAO. Uznano jednak, że włączenie danych emisyjnych łamać będzie przyjęty europejski standard metodyczny, jeśli na podstawie własnej wiedzy i inwencji włączymy te dane do analiz. Mimo bardzo licznych publikacji na temat emisji gazów cieplarnianych (GHG) nadal trudno wybrać dobry i akceptowalny powszechnie standard liczenia śladu emisji GHG. Analizy śladu emisyjnego są odrębnym zagadnieniem, które nie będzie rozpatrywane w przedstawionej publikacji.

Trendy liniowe badanych zmiennych policzono dla okresu przed transformacją ustrojową (1961-89) oraz okresu późniejszego (1990-2018). Wyjątkiem był trend biopojemności, który nie różnicował się w badanych okresach.

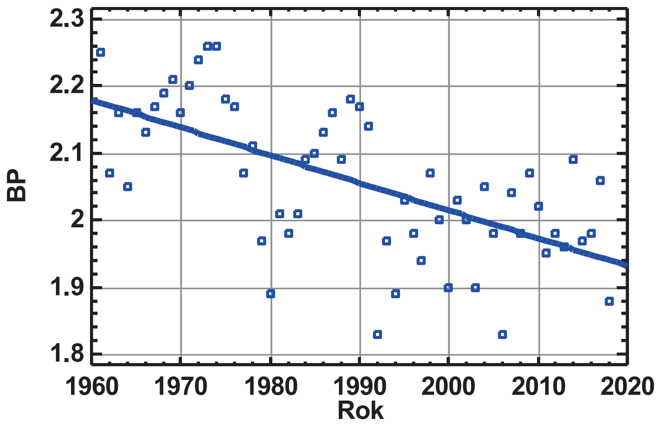
Eksploatację biopojemności obliczono jako stosunek śladu gruntowego do biopojemności i wyrażono w %.

Plony czterech podstawowych zbóż oraz stosowane dawki N i P_2O_5 na ha UR (użytków rolnych) pozyskano z bazy FAOstat[3] (FAOstat, 2023).

Wyniki badań

Biopojemność (BP) nie była wartością stałą i malała w całym badanym okresie (rys. 1). Wyszacowane z trendu wartości tego wskaźnika w 1961 i 1989 r. wynosiły odpowiednio 2,17 i 2,06 ha globalnego per capita^{-1}. W 2018 r. BP zmalała do 1,94 ha globalnego per capiata^{-1}. Spadek w stosunku do 1961 r. wynosił 11%. Omawiane wyniki pochodzą z istotnego statystycznie, ale dość słabego trendu liniowego (r^2=39,6%).

[3] Baza Danych Statystycznych Organizacji Wyżywienia i Rolnictwa, udostępnia dane statystyczne gromadzone i utrzymywane przez Organizację Wyżywienia i Rolnictwa.

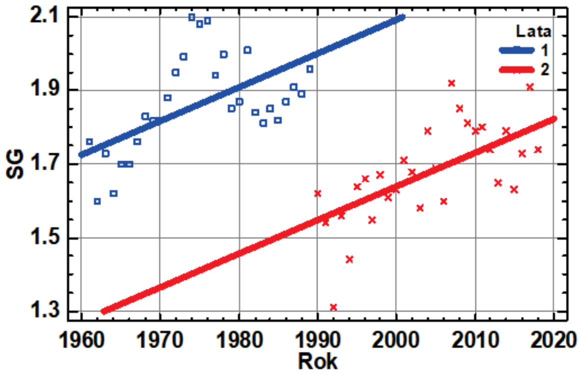


Rys. 1. Trend czasowy biopojemności (BP) wyrażonej w ha globalnych per capita^{-1} (BP=10.2 -0.00412*Rok, r^2=39,6%)

Fig. 1. Time trend of biocapacity (BP) expressed in global ha per capita^{-1} (BP=10.2 -0.00412*Year, r^2 =39.6%)

Źródło: opracowanie własne na podstawie Global Footprint Network, 2023.

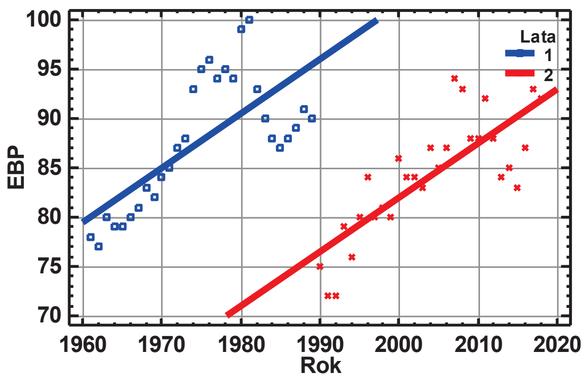
Trend czasowy śladu gruntowego (SG) nie był monotoniczny. Opisano go więc jako trendy liniowe dla dwóch badanych okresów. Współczynniki obu regresji nie różniły się istotnie, a linie trendów były przesunięte o wartość wyrazu wolnego (rys. 2). Ślady gruntowe rosły wolniej o wartość 0,45 ha globalnego per capia^{-1} w okresie 1990-2018 niż w okresie 1961-1989. Z przeprowadzonej analizy wynika, że w obu okresach badań ślad gruntowy rósł o wartość 0,00918 ha globalnego per capita^{-1} r^{-1}.



Rys. 2. Trendy czasowe śladu gruntowego (SG) wyrażone w globalnych hektarach per capita^{-1} (1 – lata 1961-1989, 2 – lata 1990-2018), (1 – SG=-16.3+0,00918*Rok; 2 – SG=-16,7+0,00918)

Fig. 2. Time trends of the ground footprint (SG) expressed in global hectares per capita^{-1} (1 – years 1961-1989, 2 - years 1990-2018), (1 – SG=-16.3+0.00918*Year; 2 – SG=-16.7+0.00918)

Źródło: jak rys. 1.



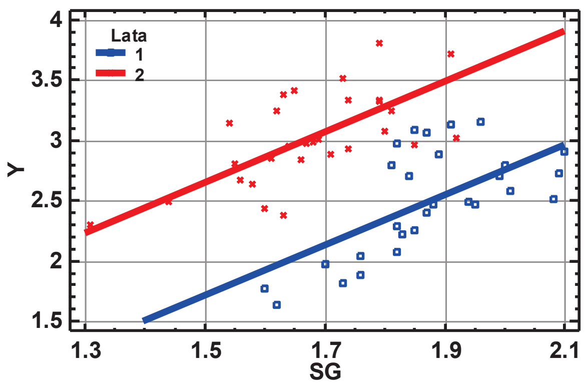
Rys. 3. Trendy czasowe eksploatacji biodostępności (EBP) wyrażone w % (1 – lata 1961-1989, 2 – lata 1990-2018), (1 – EBP=-999+0,550*Rok; 2 – EBP=1018+0,550; r^2 =57,8%)

Fig. 3. Bioavailability (EBP) exploitation time trends expressed in % (1 – years 1961-1989, 2 – years 1990-2018), (1 – EBP=-999+0.550*Year; 2 – EBP=1018+0.550; r^2 =57.8%)

Źródło: jak rys. 1.

Eksploatację biopojemności (EBP) opisywały dwie regresje liniowe. Dla badanych okresów miały one nieistotnie różny współczynnik regresji, który wskazywał, że EBP rosło o 0,550 ha globalnego per capita^{-1} r^{-1}. Regresje charakteryzowały się natomiast istotnie różniącymi się wyrazami wolnymi. Sugerują one, że EBP rosło wolniej w okresie 1990-2018 o 19,5% w stosunku do lat 1961-2018 (rys. 3). Jednakże w końcowych latach porównywanych okresów, 1989 r. oraz 2018 r., EBP wynosiły odpowiednio 95,5 oraz 91,9%. Leżały więc one blisko progu ekologicznego, co wskazuje na wyczerpywanie się możliwości intensyfikacji produkcji w Polsce.

W szacunkach BP, SG i EBP uwzględnione są produkcyjności. Poszukiwanie związków pomiędzy tymi wartościami a wielkością plonów nie ma więc sensu ze statystycznego punktu widzenia. Jednakże może unaocznić z jakim postępem mieliśmy do czynienia w analizowanych okresach. W tym jedynie celu przedstawiono regresje pomiędzy plonem czterech podstawowych zbóż a śladem gruntowym. Z przeprowadzonych szacunków wynikało, że plony w okresie 1989-2018 wzrosły o 0,94 t ha^{-1} w stosunku do okresu 1961-1989 (rys. 4).



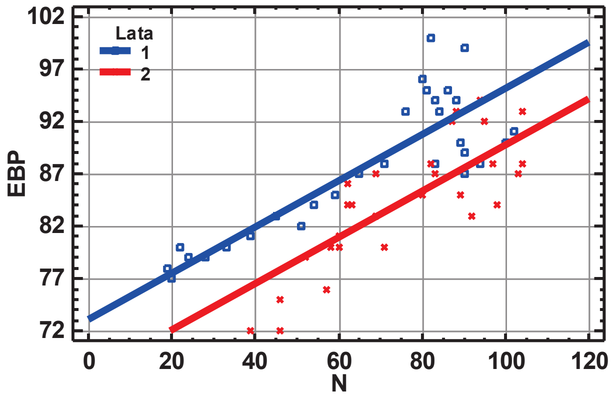
Rys. 4. Zależność pomiędzy plonem czterech podstawowych zbóż (t ha^{-1}) a śladem gruntowym (globalne ha per capita^{-1}), (1 – lata 1961-1989, 2 – lata 1990-2018), (1 – Y=-1,48+2,09*SG; 2 – Y=-0,48+02,09*SG; r^2=59,9%)

Fig. 4. The relationship between the yield of the four basic cereals (t ha^{-1}) and the land footprint (global ha per capita^{-1}), (1 – years 1961-1989, 2 – years 1990-2018), (1 – Y=-1.48+2.09*SG; 2 – Y=-0.48+02.09*SG; r^2=59.9%)

Źródło: jak rys. 1.

Odnotowany wzrost produkcyjności spowodowany był w części wzrostem nawożenia. W kontekście tego opracowania interesującym jest to, jak kształtowały się zależności pomiędzy EBP a nawożeniem azotem (N) i fosforem (P_2O_5). Te dwa składniki budzą zainteresowanie, ponieważ ich ślad w Europie przekracza 3-krotnie dla N oraz 2-krotnie dla P granice ekologiczne.

W analizowanych w tym opracowaniu okresach stwierdzono, że EBP rosło o tę samą wartość, wynoszącą 0,221% kg^{-1} N. Wzrost w okresie 1990-2018 był o 5% mniejszy w stosunku do lat 1961-1989 (rys. 5). Eksploatacja biopojemności przy maksymalnych dawkach N wynoszących 102 i 104 kg ha^{-1} w latach 1989 i 2018 osiągała odpowiednio wartości 95,6 i 90,6%, co sugeruje, że wyczerpuje się możliwość intensyfikacji nawożenia pod rygorem przekroczenia granicy ekologicznej.



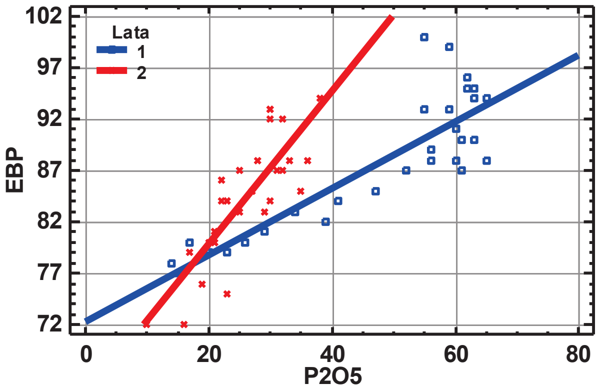
Rys. 5. Zależność pomiędzy eksploatacją biopojemności (ha globalne per capita^{-1}) a nawożeniem azotem (kg N ha^{-1}) (1 – lata 1961-1989, 2 – lata 1990-2018), (1 – EBP=73,0+0,221*N; 2 – EBP=67,6+0,22*N; r^2=69,7%)

Fig. 5. Relationship between exploitation of biocapacity (global ha per capita^{-1}) and nitrogen fertilization (kg N ha^{-1}) (1 – years 1961-1989, 2 – years 1990-2018), (1 – EBP=73.0+0.221*N; 2 – EBP=67.6+0.22*N; r^2=69.7%)

Źródło: jak rys. 1.

Inną w porównaniu z N zależność otrzymano dla P_2O_5 (rys. 6). Dawki w pierwszym okresie badań wahały się w granicach od 14 do 65 kg ha^{-1}, w drugim zaś mieściły się w przedziale od 10 do 38 kg ha^{-1}. Eksploatacja BP dla dawek maksymalnych w obu okresach była jednakowa i wynosiła 93,3%. Wynikało to głównie z faktu, że współczynnik regresji w drugim okresie był ponad dwukrotnie większy niż w pierwszym. Trudno tę specyfikę wyjaśnić.

Na podstawie przeprowadzonych analiz można stwierdzić, że biopojemność w Polsce malała liniowo w latach 1961-2018, aż o 10% (rys. 1). Wynik ten był w sprzeczności z definicją tego wskaźnika, zgodnie z którą powinien on być względnie stabilny (Global Footprint Network, 2023). Porównawcza analiza trendu czasowego dla Niemiec wykazała, że biopojemność wzrosła tam o 18% w stosunku do roku 1961 (Global Footprint Network, 2023). Wydaje się więc, że nie można przyjąć, iż wartość tego wskaźnika jest stabilna w czasie.



Rys. 6. Zależność pomiędzy eksploatacją biopojemności (ha globalne per capita^{-1}) a nawożeniem fosforem (kg P_2O_5 ha^{-1}) (1 – lata 1961-1989, 2 – lata 1990-2018), (1 – EBP=72,3+0,325* P_2O_5; 2 – EBP=65,0+0,745* P_2O_5; r^2=73,6%)

Fig. 6. The relationship between the operation of biocapacity (ha global per capita-1) and phosphorus fertilization (kg P_2O_5 ha-1) (1 – years 1961-1989, 2 – years 1990-2018), (1 – EBP=72.3+0.325* P_2O_5; 2 – EBP=65.0+0.745*P_2O_5; r^2=73.6%)

Źródło: jak rys. 1.

W ocenie wielkości biopojemności w Polsce istotnym jest jej odniesienie do wartości tego wskaźnika w sąsiednich Niemczech i różnych rejonach Europy (tab. 1). Z porównania wynika, że mamy biopojemność nieco większą, niż w Niemczech i Europie Zachodniej, ale znacznie mniejszą niż w całym regionie Europy Wschodniej oraz Europy Północnej. W tych ostatnich regionach istnieją najlepsze warunki rozwoju biogospodarki z ekologicznego punktu widzenia.

Tabela 1. Biopojemność i ślad gruntowy (ha globalne per capita^{-1}) w Polsce, Niemczech oraz rejonach Europy w 2018 r.
Table 1. Biocapacity and ground trail (ha global per capita-1) in Poland, Germany, and European regions in 2018

Kraj/region	Biopojemność	Ślad gruntowy	Eksploatacja biopojemności
Polska	1,88	1,74	93
Niemcy	1,49	1,63	109
Europa Wschodnia	5,09	1,76	35
Europa Północna	3,25	2,09	64
Europa Południowa	1,27	1,77	139
Europa Zachodnia	1,72	1,81	105
Europa	2,99	1,83	61
Świat	1,58	1,09	69

Źródło: opracowanie własne na podstawie Global Footprint Network, 2023.

Ślady gruntowe rosły w latach badań w jednakowym tempie (rys. 2). Jednakże w latach 1990-2018 były mniejsze o 0,45 ha globalnego per capita-1 w porównaniu do okresu 1961-1989. Sugeruje to, że w ostatnim trzydziestoleciu presja gruntowa w Polsce zmalała i to o wcale niebagatelną wartość. Niemniej jednak, w 2018 r. ślad gruntowy był większy niż w Niemczech i mniejszy niż w regionach Europy (tab. 1).

Eksploatacja biopojemności w Polsce rosła w jednakowym tempie w obu badanych okresach (rys. 3). Jednakże w okresie 1990-2018 była mniejsza niż w poprzednim o 19,5%. W 2018 r. wynosiła ona w Polsce 93% i zbliżała się do progu ekologicznego (100%). W Niemczech, Europie Południowej i Zachodniej próg ekologiczny został przekroczony, co wskazywałoby, iż należy tam zmniejszyć intensywność biogospodarki (tab. 1). Dla odmiany, znaczny potencjał rozwoju biogospodarki, z ekologicznego punktu widzenia, istnieje w Europie Wschodniej i Północnej (tab. 1).

Zwiększenie produkcyjności w biogospodarce prawie zawsze pociąga za sobą wzrost śladu gruntowego (Liobikiene i in., 2019; Liobikiene i in., 2020). Nazywane jest to sprzężeniem produkcyjności i śladu. W Polsce plony czterech podstawowych zbóż rosły w jednakowym tempie w okresach badań. Jednakże w latach 1990-2018 były większe o 0,94 t ha^{-1} (rys. 4). Na podstawie dostępnych dla nas danych nie było możliwym pogłębienie analizy pomiędzy wartością dodaną biogospodarki i śladem gruntowym. Z literatury wynika jednak, że rozprężenie wartości dodanej produkcji i śladu gruntowego zanotowano w Europie jedynie w Danii (Liobikiene i in., 2020). W Polsce stwierdzono zerowy przyrost śladu wraz ze wzrostem wartości dodanej produkcji (Liobikiene i in., 2020), co jest dobrym wstępem do dalszego rozprężania zależności pomiędzy tymi zmiennymi.

Podsumowanie

Jednym z głównych wyzwań współczesnego świata jest zapewnienie bezpieczeństwa żywnościowego, ochrona środowiska przyrodniczego, przeciwdziałanie zmianom klimatu i zrównoważone wykorzystywanie zasobów naturalnych, co jest szczególnie istotne w świetle prognoz dotyczących dynamicznego zwiększania populacji ludności i związanej z tym coraz większej skali eksploatacji zasobów naturalnych. Strategia zrównoważonego rozwoju względem tych wyzwań jest jedną z najważniejszych idei UE. W strategiach i programach politycznych coraz częściej zwraca się uwagę na rosnącą rolę biogospodarki jako możliwej drogi do rozwiązania problemu wyczerpywania się zasobów naturalnych. Proces rozwoju biogospodarki powinien bazować nie tylko na produkcji biozasobów o niewielkim wpływie na środowisko, ale również na ich zrównoważonym użytkowaniu pod względem ekologicznym, gospodarczym i społecznym. W dążeniu społeczeństw do podwyższania wskaźnika ludzkiego dobrobytu przy realizacji strategii biogospodarki, koniecznym jest aby biozasoby (potencjał biomasy) nie zostały wyczerpane. Dlatego też istotne znaczenie ma wskazanie metod ograniczenia presji człowieka na środowisko i nie przekraczania progów ekologicznych.

Przeprowadzone badania wykazały, że biopojemność w Polsce malała w całym analizowanym okresie co stało w sprzeczności z definicją wskaźnika mówiącej o jego stałości. Natomiast ślady gruntowe rosły w latach badań. Jednak w ostatnim okresie (1990-2018) były o 0,45 ha globalnego per $capita^{-1}$ mniejsze w porównaniu do okresu 1961-1989 co świadczy o malejącej presji na środowisko. Podobną tendencję stwierdzono dla eksploatacji biopojemności. Jednakże w 2018 r. wynosiła ona 93% i była bliska bariery ekologicznej. Porównanie uzyskanych wyników z odpowiednimi wartościami dla Niemiec i innych rejonów Europy pozwoliło stwierdzić, że większe możliwości rozwoju biogospodarki z ekologicznego punktu widzenia istnieją w całym regionie Europy Wschodniej i Północnej.

Zrozumiałym jest, że istnieją rosnące zależności pomiędzy wielkością śladu gruntowego a zużyciem środków produkcji. W tym opracowaniu przedstawiono je dla azotu i fosforu, dla których ślady globalne przekroczone zostały odpowiednio 3- i 2-krotnie (EEA, 2020). Uzyskane zależności wskazują, że w latach 1990-2018 eksploatacja biopojemności poprawiła się dla azotu, a w przypadku fosforu pogorszyła w stosunku do wcześniejszego okresu. Wynik dla fosforu jest nieoczywisty i wymagałby głębszych analiz.

Reasumując można stwierdzić, że ekologiczny potencjał zwiększenia produkcji biomasy w Polsce jest mały. W tej sytuacji istnieją dwie możliwości pokrycia zapotrzebowania na biomasę: 1) zwiększenie produkcyjności bez zwiększania zużycia środków produkcji oraz 2) zwiększenie wykorzystywania biomasy ubocznej i odpadowej. Realizacja obu ścieżek wymaga innowacji technologicznych.

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Economic Consequence of Human - Hippopotamus (*Hippopotamus amphibious*) Conflicts on Farming Livelihood in Rural Adamawa State, Nigeria

Abstract. Human-animal conflict is posing a severe threat to wildlife conservation as well as the long-term viability of farming communities. This study assessed the economic consequence of human-hippopotamus (Hippopotamus amphibious) conflicts on rural livelihoods in Adamawa state, Nigeria. The study had the following specific goals; describe the direct effects of Human Hippopotamus Conflict (HHC) on livelihoods in the study area, and estimate the agricultural economic losses incurred in the area as a result of HHC. A mixed research method was used to collect primary data from 371 crop farmers. The study relied on descriptive statistics in the analysis of the data collected between February to May 2019. The study found that Groundnut, Cowpea, and maize were among the most severely damaged crops at their mid-stage of development based on land size. In terms of the monetary value of the damages, sweet potato is the most affected. The study concluded that farmers should work as a team and adopt measures like fencing, scare tactics, or deterrents that will minimize significant crop losses. Also, there is the need for local awareness on the importance of Hippopotamus conservation in the area.

Key words: human-hippopotamus, conflict, economic losses, Adamawa State

JEL Classification: Q1, Q18, Q12, J18

Introduction

Human-Hippo conflicts are recurrent issues in wildlife conservation throughout affected areas worldwide, and have negative impacts on both human and wildlife populations (Dossou et al., 2019). Human-Hippo conflict denotes any instance in which the resource demands of humans and Hippos overlap, spurring competition for food, space, and water and thus creating tension between people and Hippos (Messmer, 2000; Seoraj-Pillai & Pillay, 2017). Hippopotamus (Hippopotamus amphibious) are among Africa's most destructive crop raiders (Lamarque et al., 2009; Baker et al., 2020). In Adamawa state, while the exact population of Hippopotamus in the riverine communities is not exactly known, (Baker et al.2020) it is estimated to be about 45 animals around Kiri dam reservoir. The conflicts emerge as a result

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of direct and indirect negative interactions, resulting in agricultural losses due to crop destruction, human fatalities and injuries, livestock predation, and retaliatory wildlife murders (Chardonnet et al., 2010). These conflicts hamper the peaceful habitation of humans and wildlife and constitute major threats to the survival of many wildlife species. According to Kahler & Gore (2015), these conflicts include how people perceive risks associated with negative interactions with wildlife. The conflicts have resulted in the destruction of food crops or harm by hippopotamuses, thereby affecting rural livelihoods or injury/ killing of the hippopotamuses by affected persons, which then also affects wildlife conservation. Such conflicts not only endanger the hippopotamus population but also have a severe impact on the local economy and people's livelihoods owing to crop loss (Dossou et al., 2019). According to Backer et al. (2022), between 2012-2017, about 6 persons were killed by hippopotamus in Adamawa state.

This challenge varies with location in terms of its nature and severity, based on human population growth rates, conservation measures, and scarcity of essential natural resources – particularly land and water resources available for wildlife (Conover, 2002; Institute of Policy Analysis and Research, 2005; Akinsorotan et al., 2020). Equally, the issue of climate change is one of the leading causes of human-Hippopotamus conflicts (Ba et al., 2014). Generally, hippopotamuses require large areas of savannah grasslands, where they feed on stems of herbaceous species, and in times of food stress, they will also feed on cultivated crops (González et al., 2017). However, due to these outlined factors, there have been pressures on land resources that have resulted in a reduction of core habitats for hippopotamus, curtailed hippopotamus movements, and accessibility to feed resources (Conflict-sensitive approaches, 2009). This has led to a substantial decrease in the quantity and quality of hippopotamus feed resources while exacerbating human-hippopotamus conflicts in terms of crops damage, killing of domestic animals, hippopotamus, and humans (Thornton et al., 2008; Madden, 2008; Joseline, 2010; Manga et al., 2013; and Ertiban, 2016).

Damage by wildlife could significantly affect the livelihood of the affected households both directly and indirectly (Akinsorotan et al., 2020). The conflicts have a wide variety of direct implications on human livelihoods, from nuisance behavior like reduced leisure opportunities to crop damage, livestock depredation, fatal human attacks, and zoonotic disease transfer to humans or cattle (Michel and Bengis, 2012). According to the International Union for Conservation of Nature (IUCN) Redlist, hippopotamus populations have fallen by 7% to 20% in the last decade as a result of habitat degradation and illicit and uncontrolled meat and ivory poaching (Lewison & Oliver, 2008; Igidi, 2014). Its indirect consequence is that it has a negative impact on the afflicted individuals' psychological health and social well-being by instilling fear and restricting movement (Barua et al., 2013; Brashares et al., 2014; Mukeka et al., 2019). Understanding risk perception is important in tackling Human-Hippo conflict because it can impact the behavior of key participants in conflicts, including farmers and conservationists (Kahler & Gore, 2015; Ertiban, 2016). In Adamawa State, human-hippopotamus conflicts have been found to impact negatively on conservation and jeopardize human livelihoods and safety. This has been witnessed in the southern and central part of Adamawa State where human-Hippopotamus conflicts have persisted over the years (Daily Trust, 2014). Over the years, there has been increasing effort by conservators to effectively resolve human-hippopotamus conflicts (Linnell et al., 2010). Most of these efforts tend to concentrate on hippopotamus management without regard to the community's opinions. The lopsided nature of these efforts is contributory to the persistence of human-hippopotamus conflicts in most areas (Masumbuko and Somda, 2014). The riverine communities in

Adamawa State engage in a variety of livelihood activities such as fishing, farming, and trade. These activities are essential for their survival and provide a source of income for the people in the area (Abubakar et al., 2020).

In analyzing the impact of wild animals on human interests, it is important to consider the species involved and the scale of damage caused (Chomba et al., 2012). Such information can significantly contribute to the development of a strategy that will comprehensively address human-wildlife conflict. In the last century, there was a decrease of about 7-20% in the number of common hippopotamuses. This decline was attributed to human activities, consequences, mainly habitat loss as wetlands are converted or impacted by agricultural development (Dossou et al., 2019). It is critical to understand the economic effects of these conflicts on the livelihoods of those affected in order to properly protect wildlife resources and minimize crises. As a result, the goal of this study was to address a vacuum in the literature on human-hippopotamus conflict in rural Adamawa State. The study's specific objectives were to:

i. describe direct effects of Hippopotamus activities on livelihoods of farmers in the study area;
ii. estimate the agricultural economic losses incurred in the area as a result of the conflicts.

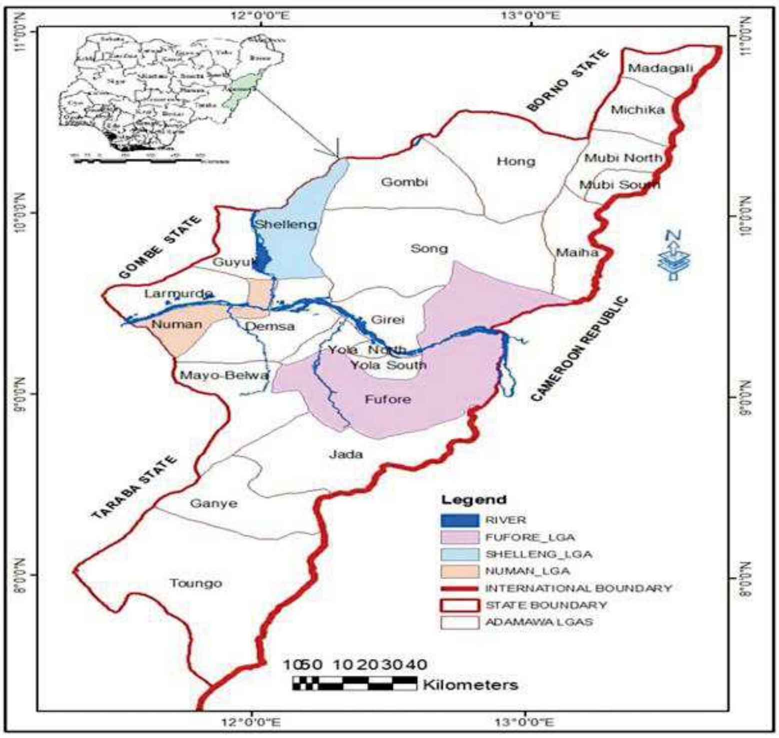

Fig. 1. Map of Adamawa State showing the Study Area

Source: GIS Lab, Modibbo Adama University Yola, 2019.

Methodology

The study was conducted in communities affected by hippopotamus activities in Adamawa State as shown in Figure 1. Geographically, the State is located between 70° and 11' north latitude and 11° and 14' east longitude of the Greenwich Meridian. As a result, the state is claimed to be in Nigeria's Northeastern region, with Taraba State to the south and west, Gombe State to the northwest, and Borno to the north. Along its eastern border, it also shares an international border with the Republic of Cameroon (Adebayo and Zemba, 2020). The state has a landmass of around 38,741 km^2 and a population of 4.254 million people (National Bureau of Statistics, 2021). Hippopotamus activity is abundant in the area's primary water bodies, Benue, and Gongola. The Gashaka Gumti National Park, in the extreme south of the state, is home to significant numbers of wild species (Briggs, 2018). In terms of livelihoods, the state is agro-based, with the entire economy depending mostly on crop and livestock production. Along the riverbanks, fishing and dry-season farming are common.

Data Collection

The study adopted a mixed research method in collecting the data. Firstly, seven communities across the three most affected Local Government Areas were purposively selected. Namely, Babbandaba, Gonlong, Talum, and Gundo in Shelleng LGA; Gurin and Ribadu in Fufore LGA; and Imburu in Numan LGA. Following Kagiri (2005), the direct observation method was adopted for this study. This involved the identification of all protected crop farms of not less than 1 hectare and an equal number of unprotected ones within each location. A total of 371 crop farmers were purposively selected because of the effects of hippopotamus activities on their farms. The farms were actively monitored throughout the growing season and the following were recorded: type of crops damaged, the stage of growth of the time of damage, and part of crops damaged. Similarly, economic losses were estimated using the method outlined by Jones et al. (2008) which were as follows:

i. the crops that were damaged were identified,
ii. the yield of each crop per hectare in the absence of damage by hippopotamus was obtained,
iii. the total yield of each crop as a result of the damage was obtained,
iv. the prevailing market price of the produce from each crop was also obtained from the nearby market. and
v. the monetary loss on each crop was then obtained based on the difference in the amount realizable from the produce under optimum yield without damage and that obtained after damage.

Data Analysis

Data on conflict areas, crop damage, stage of growth of damaged crops, parts of crops damaged, and monetary losses in Naira and Dollar were analyzed using appropriate descriptive statistics such as tables, percentages, and charts. The direct observation method (Kagiri, 2005) was used to assess the conflict areas and determine the economic losses incurred by the participants in the period under review.

Results and discussion

Demographic characteristic of the respondents

In Table 1, the respondents' demographic characteristics were described. Based on the respondents' age breakdown, 15.77% were below 30 years, 31.02% were between 30 and 39, and 28.51% were between 40 and 49. The proportions of respondents aged 50 to 59 years and 60 years and older were 15.40% and 9.30%, respectively. According to the results, 18.76% of respondents were female, compared to 81.24% of males. This shows that the majority of local farmers are men. 20.14% of people were single, compared to 79.86% who were married. According to the household sizes of the respondents, homes with 1 to 5 people made up 20.39%, while households with 6 to 10 people, 11 to 15 people, and more than 15 people made up 33.75%, 28.08%, and 17.78%, respectively. This result shows a rather sizable household that can provide family labor for farming tasks. The distribution of respondents' educational levels shows that those with no formal education made up 28.22% of the sample, those with primary education made up 34.82%, and those with secondary and tertiary education made up 26.14% and 10.82%, respectively. Similarly, the respondents' farm size revealed that the majority (79.23%) of them cultivate between 1 and 5 ha, while just 20.77% of them cultivate more than 5 ha. In terms of farming experience, 37.96% had 1-10 years' experience in farming, while those with 11-20 years and more than 20 years constituted 35.76% and 26.28% respectively.

Table 1. Description of the Respondents Socio-Demographic Characteristics (n=371)

Variable	Frequency	Percentage	Variable	Frequency	Percentage
Age (years)			**Educational Attainment**		
<30	59	15.77	No formal education	105	28.22
30-39	115	31.02	Primary	129	34.82
40-49	106	28.51	Secondary	97	26.14
50-59	57	15.40	Tertiary	40	10.82
≥60	35	9.30	**Farm size (ha)**		
Gender			1-5	294	79.23
Female	70	18.76	6-10	72	19.46
Male	301	81.24	>10	5	1.31
Household Size (number of people)			**Farming Experience (years)**		
1-5	76	20.39	1-10	141	37.96
6-10	125	33.75	11-20	133	35.76
11-15	104	28.08	>20	97	26.28
≥15	66	17.78	**Marital Status**		
			Married	296	79.86
			Unmarried	75	20.14

Source: Field survey 2019.

Direct effects of human-hippo conflict on livelihoods

The distribution of the effects of Hippopotamus activities on the respondents is presented in Figure 1. Findings of the study across communities revealed that crop damage was the most common (averaged 79.1%), followed by livestock predation (9.6% on the average), and attack on human beings (2.4%).

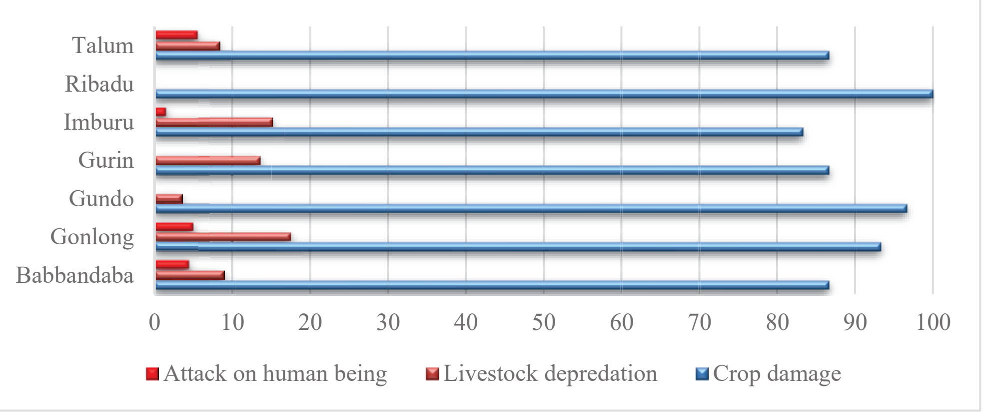

Fig. 1. Effects of hippopotamus activities in the study area (n=371)

Source: Field survey 2019.

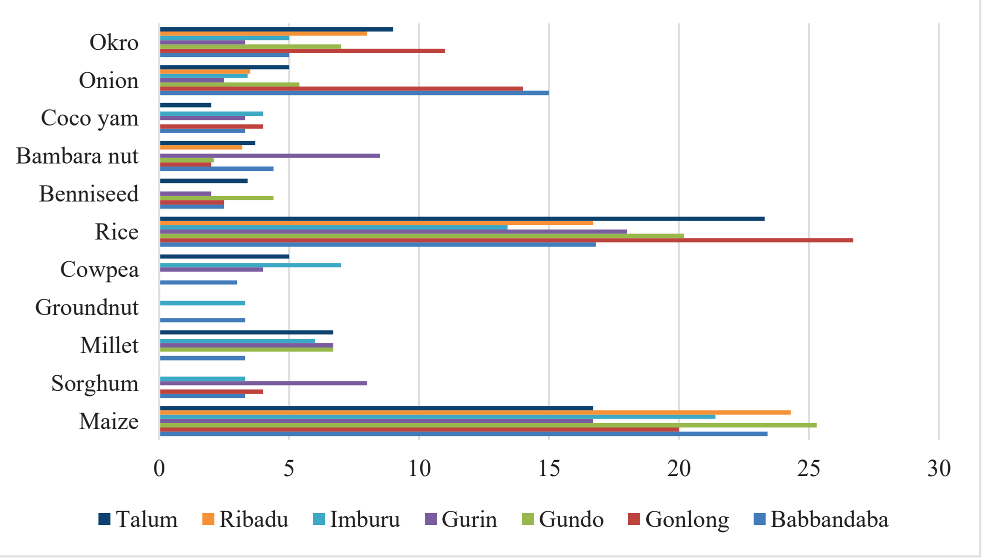

Fig. 2. Major crops damaged by hippopotamus in the study area (n=371)

Source: Field survey 2019.

The distribution of the major crops damaged by hippopotamus in the study area is shown in Figure 2. The findings of the study indicated that across the communities, maize was the most (21.9%) affected crop on average. This was followed by rice (18.6%), onion (7.3%), and okro (6.6%). Similarly, millet (3.8%), Bambara nut (3.4%), sorghum (3.1%), and cocoyam (2.4%) were also destroyed by the hippopotamus. Equally, the respondents reported that cowpea (2.3%), benniseed (1.9%), and groundnut (1.1%) were also destroyed in the area. This finding lends credence to the submission of Adeola et al. (2022) who also reported that Maize, Beans, Millet, Guinea corn, Rice and Groundnut are affected by Hippopotamus in Selected Communities around Kainji Dam in New-Bussa, Niger State, Nigeria.

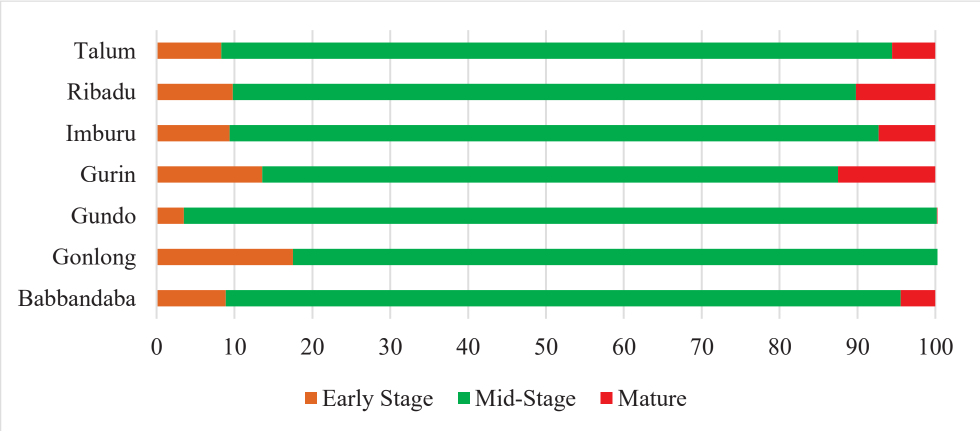

Fig. 3. Stages at which crops were damage by hippopotamus in the study area (n=371)

Source: Field survey 2019.

This study also assessed the level at which the crops were damaged by the hippo and the result is presented in Figure 3. The finding of the study revealed that the majority (85.7%) of the crops were damaged at their mid-stage of development, while 10.1% and 7.9% of the crops were damaged at early and mature stages of development respectively. However, it is worth noting that the extent of crop damage caused by hippos can vary depending on the specific circumstances, including the availability of other food sources, the proximity of water bodies, and the effectiveness of deterrent measures implemented by farmers or local communities (Bayani et al., 2016). The finding of this study is in line with that of Dossou et al. (2019) who revealed that the main damage caused by common hippopotamus was crops raiding, which occurs in farmlands during the whole year in central Benin Republic.

Estimate of economic losses due to crop damage as a result of human-hippo conflict

The result of economic losses due to crop damage by hippopotamus is presented in Table 2. The respondents were grouped into three categories based on their farm sizes, and the economic losses incurred were computed based on the average size of farm destroyed and the average market price of the affected commodity. Among small-scale farmers, sweet potato and coco yam were the most affected crops based on market value of ₦241,115.0 and

₦105,000.0 respectively. Hippos are primarily herbivorous animals and feed on various types of vegetation, including aquatic plants, grasses, and even crops in some cases. However, hippos are not known to specifically target tubers like sweet potatoes or cocoyam as a significant part of their diet. However, while roaming for feed, when hippos trample on these tubers, they cause considerable damage to the product physically, thereby reducing the shelf-life and market value of the commodity. Equally, cereal crops like maize, rice, and sorghum are also affected by hippos in the study area. The economic losses averaged ₦38,025.0, ₦33,540.5, and ₦103,873.0 respectively for the crops. Furthermore, among medium-scale farmers, Maize, Rice, Groundnut, Onion, and Sweet Potato were the affected crops.

Table 2. Estimate of economic losses due to crop damage in the area (n=371)

Crop	Expected output without damage (kg/ha)	Average size of farm destroyed (%)	Average yield damaged	Average market price/100kg (₦[5])	Total estimated loss (₦)
Small-Scale Farmers (1-5 ha)					
Maize	1500-3000	65	1462.5	2600	38,025.0
Rice	2000-5000	37	1295.0	2590	33,540.5
Sorghum	800-1500	44	2090.0	4970	103,873.0
Groundnut	800-1500	69	793.5	1380	10,950.3
Cowpea	500-1500	65	650.0	6000	19,200.0
Bambara nut	500-1500	32	320.0	6500	21,450.0
Benniseed	300-800	60	330.0	5400	17,982.0
Okro	800-2000	30	150.0	1200	1,800.0
Onion	1500-3000	57	1282.5	2850	36,551.3
Sweet Potato	5000-15000	53	8300.0	2905	241,115.0
Cocoyam	8000-20000	50	7000.0	1500	105,000.0
Medium-Scale Farmers (6-10 ha)					
Maize	1500-3000	28	630.0	2600	16,380.0
Rice	2000-5000	31	1085.0	2590	28,101.5
Groundnut	800-1500	29	333.5	1380	4,602.3
Onion	1500-3000	21	472.5	2850	13,466.3
Sweet Potato	5000-15000	24	2400.0	2905	69,720.0
Large-Scale Farmers (>10 ha)					
Maize	1500-3000	17	382.5	2600	9,945.0
Rice	2000-5000	15	525.0	2590	13,597.5
Groundnut	800-1500	21	241.5	1380	3,332.7
Sweet Potato	5000-15000	19	1900.0	2905	55,195.0
Onion	1500-3000	12	270.0	2850	7,695.0

Source: Field survey, 2019.

However, sweet potato and rice were the most prominently affected to the tune of ₦69,720.0 and ₦28, 101.5 on the average respectively. In terms of the large-scale farmers also, sweet potato and rice were the most prominently affected. The migration or movement patterns of hippos in Nigeria may vary depending on factors such as the availability of water and food resources, as well as human activities in the area (Baker et al., 2022). In Adamawa State, it is generally known that hippos tend to move around more during the dry season, and early parts of the rainy season (February-July) when water sources become scarce and competition

[5]At the time of the study, $1 USD was worth 360 Naira, according to the official exchange rate of the Central Bank of Nigeria.

for resources increases (Radda, 2015). During this time, hippos may travel long distances in search of new water sources or better grazing areas. As they move, they may come into contact with human settlements, which can lead to human-wildlife conflicts and potential attacks (Baker et al., 2020).

HWC (human-wildlife conflict) is fast becoming a critical threat to the survival of many globally endangered species (Distefano, 2005; Cromsigt et al., 2013; Manral et al., 2016). While it is still difficult to reliably estimate the socio-economic and financial implications of human-wildlife conflicts on affected livelihood (Mhuriro-Mashapa et al., 2018), there is a need for actors to have a sound understanding of the level of impacts and drivers (White & Ward, 2010). Knowing this will substantially impact conservation policies and human wellbeing in affected communities (Barua et al., 2013). This study has established a multidimensional consequence of Human-Hippo Conflict between crop farmers and hippopotamus in the study area. This study revealed that crop damage was the major conflict in the area. This finding lends credence to the submission of Kanga et al. (2011) who reported similar outcomes in a study carried out in Kenya, which investigated human-hippopotamus conflict within support zones of the park. The damage done to crops by hippopotamuses in the study area has a significant effect on household livelihood as they attack most economic crops cultivated by the residents in the area. As opined by Barua et al. (2013), crop damage is the most prevalent form of human-wildlife conflict in Africa, and this impoverishes economically depressed households that rely on farming for sustenance.

Investigation into crop damage by hippopotamus in all the study locations within the study area revealed that rice and maize suffered the highest raiding. Hippopotamus raided other crops such as guinea corn, millet, groundnut, and beans. This finding is not unexpected as it aligns with the feeding habit of the hippopotamus. It also agrees with the report of Shefferly (2001) that the hippopotamus is a grazer, preferring short grasses. Rice, maize, guinea corn, and millet are cereals and therefore types of grass. The preference shown for rice and maize may not be unconnected with their palatability since guinea corn and millet are equally accessible and available in the study area, and yet not preferred. This result is similar to the findings of Shalangwa et al. (2014).

Investigation into crop-raiding in relation to stages of development of the crops indicated that the pattern of crop-raiding varied with the stage of growth of the crops. The findings showed that the mid-stage of crops was the most raided stage by hippopotamus in all the locations of the study area. The mid-stage growth consumption was followed by the consumption at the early-stage growth, while the mature stage growth was the least consumed. Observations of the crops on the farms showed that the mid-stage growth provided succulent stems and leaves in addition to relatively higher biomass than the early-stage growth. Besides, the succulent nature of the crops at the mid-stage growth is higher than at the mature stage of development. The implication is the availability of more palatable and higher biomass crops at the mid-stage growth. This situation might have influenced the preference shown by the hippopotamus towards crops at the mid-stage development. Similar findings were made by Wilbroad et al. (2011) and Gross et al. (2015).

Further findings from the investigation into the pattern of crop-raiding showed that hippopotamuses prefer the stems and leaves of the crops to their fruits, bulbs, and seeds. The findings also showed that they do not damage the roots. The selection of stems and leaves and the preference for mid and early stages of the crops by the hippopotamus may not be unconnected with the relatively high protein and low fiber content of the freshly sprouting crops. This observation agrees with the report of Martin (2005) on the feeding habit of hippopotamus in the Caprivi region of Namibia.

The human-hippopotamus conflict investigated in this study involved food crop-raiding, hence most of the economic losses were on food crops. A total of twelve (12) food crops were raided by the common hippopotamus. The food crops included maize, rice, millet, sorghum, cowpea, benniseed, Bambara nut, cocoyam, groundnut, onion, okra, and sweet potato. Losses incurred as a result of the conflict have a monetary implication on the household economy. This implied that the hippopotamus could induce both food insecurity and poverty in the study area. Food and economic losses will continue to plague the rural population if indeed the issue persists unabated. With the rapid reduction of hippopotamus grazing land, this is likely to intensify. Mulu (2010) made a similar observation in similar research in Kenya.

According to Treves et al. (2006), where multiple stakeholders are affected in different ways by HWC, the conflict situation becomes more complex, since a desirable outcome requires an understanding of the impacts on the different stakeholder groups and an appreciation of the different attitudes that these groups may hold regarding both the level of impacts and the focus and outcome of management to reduce them. As a result, when wildlife roams freely on crops, harms livestock, or somehow threatens human security, conservationists must examine the economic and socio-political repercussions. This is because apart from the visible impacts of this conflict, other associated or hidden costs include opportunity and transaction costs that occur as a result of conflict, as well as health impacts that impair people's physical and mental wellbeing (Barua et al., 2013).

Conclusions and recommendations

In conclusion, the conflict between humans and hippopotamuses has a considerable and detrimental impact on farming in Adamawa state. The findings revealed that crop raiding is the major cause of conflict between humans and hippopotamuses in the study area. Crop loss, livestock raiding, hippo mortality, and habitat disturbance are the main repercussions of the presence of high conflicts in the study area. Crops raided by hippopotamus included both food and cash crops (maize, rice, millet, groundnut, guinea corn, and cowpea). Further investigation showed that the conflict has induced both food insecurity and poverty in the study area. Effective hippo management techniques and community-based interventions that give farmers and other stakeholders the capacity to safeguard their livelihoods and lower the risks associated with living near waterways will be necessary to address these disputes. As a result, determining feasible methods to decrease Human-Hippo conflict in the research region is essential for human- Hippo cohabitation. The following points in the study region are proposed based on the findings of this study:

i. Farmers should work together to protect their farmlands from crop raiders, using the most effective means available in their area like fencing, scare tactics using noise and light, or deterrents like scarecrows, reflective materials or even employing guards to deter the animals and protect agricultural areas.
ii. There is the need to educate local communities about the importance of hippo conservation and the potential risks and benefits. Coexistence can foster understanding and support for conservation efforts. Encouraging responsible

land use and promoting sustainable farming practices can also contribute to reducing conflicts.

iii. Human settlements around water sources where these animals live should be removed by the authorities.

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Implications of Prevalence and Intensity of Soil-Transmitted Helminthes (STHs) on Rural Farmers' Productivity in Selected Districts of Sierra Leone

Abstract. Soil-transmitted Helminths (STH) are among the most prevalent parasitic diseases that impair childhood physical and mental growth, hence hindering economic development. The study was a cross-sectional-designed survey, conducted in three districts in Sierra Leone between December and March 2022 on 625 individual farmers to determine: 1) the prevalence of soil-transmitted helminths; 2) the intensity of soil-transmitted helminths; 3) the effect of the prevalence and intensity on farm productivity, and 4) the implication of these effects on agricultural extension service delivery and the rural livelihood of the selected districts. Stool samples were collected from male and female farmers in fifteen chiefdoms in the selected districts and analyzed using the Kato-Katz technique. A total of 625 individuals were included, among whom 172 (27.0%) were vegetable farmers, 224 (35.8%) were tree-crop farmers and 226 (36.2%) were rice farmers. The result indicates a prevalence of parasitic infection among farmers shown by 58.4% eggs/ova in stool from the three districts. STH prevalence is higher in Bo (64.0%), Koinadugu (56.9%), and Kailahun (51,7%). STH infections, in various ways, affected extension services, delivery and the livelihoods of individual farmers. The recommendation is that farmers and children be periodically dewormed for STH infection in rural areas.

Keywords: soil-transmitted helminths, prevalence, intensity, farm productivity, extension services, rural livelihood

JEL Classification: R2, I15, P46

Introduction

Soil-transmitted helminth (STH) infections refer to groups of parasitic diseases caused by nematode worms transmitted to humans by fecally contaminated soil, food and water (Zeleke et al., 2020). Soil-Transmitted Helminth infections of humans fall within the World Health Organization's (WHO) grouping termed neglected tropical diseases (NTDs), forgotten diseases or diseases of the poor (Fantal et al., 2020). The soil transmitted helminths of significant concern to humans includes the roundworm (Ascaris lumbricoides), the

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whipworm (Trichuris trichiura), and the hookworms (Necator americanus and Ancylostoma duodenale) (Hosea, Kator, and Philomena, 2019). Other species such as Strongyloides stercoralis, Enterobius vermicularis, and Toxocara cause hookworm infection, and Strongyloides stercoralis are transmitted by direct skin penetration while the rest gain entry by oral route. Enterobius spp., by autoinfection, enters children when they scratch their anus, fidget with their mouths or eat with unwashed hands (Brummaier et al 2021; Hassan and Oyebamiji, 2018). WHO (2018) linked soil-transmitted helminth infection to rural poverty, inadequate sanitation, waste disposals, lack of clean water supply, poor hygiene, limited access to health care and preventive measures such as health education. Polyparasitism occurs where different parasites co-exist (GBD, 2019), and when there is poor sanitation Simiyu (2022). Though soil-transmitted helminths rarely cause death, they significantly impact public health and lead to severe disability in the world's poorest countries (Brummaier et al 2021). The parasites can impair intellectual and physical development, significantly diminish economic productivity, and cause disabilities, resulting in stagnation and perpetuation of the poverty cycle (Cools et al, 2019).

Ascaris lumbricoides, Ancylostoma duodenale, Necator americanus, and Trichuris trichiura infections are soil-transmitted helminth (STH) infections that affect around 1.5 billion individuals globally (Ercumen et al., 2019). Since disease transmission primarily occurs through contact with soil contaminated with infected human feces, low- and middle-income countries (LMICs) that lack sufficient water, sanitation, and hygiene (WASH) are disproportionately affected by the disease burden (Khan et al., 2019).

In Sierra Leone, transmitted helminths are distributed across the country, with high prevalence of hookworm infections, particularly in the north and east districts of Koinadugu (range 21.6-82.1%), and Kailahun (range 43.5-52.6%) respectively and part of Bo District (Koroma et al., 2010). Soil-transmitted helminth affects not only people with limited resources but also indigenous groups, women of childbearing age, smallholder farmers in rural areas, migrant workers, prisoners, and refugee groups (Kabir et al., 2019). Other groups at high risks of these parasitic infections include preschool-age children (aged 1-4 years), school-age children (aged 5-14 years), pregnant women in their second and third trimesters and lactating mothers, vegetable farmers, sand miners, people who fish in stagnant waters, tree-crop harvesters and processers (Dabasa et al.2017; WHO, 2020). Realistically, farmers rank second to school-going children in harbouring multiple helminth species, though the impact of these parasites infections on them is still neglected in the helminthological literature (Pratinidhi et al., 2020).

Soil-transmitted helminth larvae develop in tropical and sub-tropical climates, with warm temperatures, high humidity and moist soils that are suitable for farming. Furthermore, unhygienic sanitation, inadequate water supply and untreated night-soil fertilizer are the environmental factors that favor soil-transmitted helminth buildups (Shumbeji et al.,2019; Jourdan et al., 2018).

The other behavioral risk factors include toilet usage, non-shoe wearing, personal hygiene and other habits such as inappropriate hand washing and eating raw food. Occupations with high soil contact during farming also increase the risk of soil-transmitted helminth infection (Center for Disease Control and Prevention, 2022). Both these environmental and behavioral risk factors commonly occur in poor socio-economic conditions, making poverty and limited education one of the critical risk factors for soil-transmitted helminth transmission (Grimes et al., 2018).

Educating, motivating and introducing rural farmers to use low-cost pit latrines improves and protects their farm families against parasitic worms (Oswald et al., 2017). But, where water supplies and sanitation are poor, without preventive measures, farmers and travelers are exposed to soil-transmitted helminth (Chard et al.2019). Since these worms do not multiply in hosts, reinfection occurs only due to additional contact with the infective stages. In fact, according to Hossain et al. (2018) and the WHO (2019) guiding principles, deciding to treat individuals (mass treatment) or only school children and other high-risk groups (selective treatment) once or more times a year depends on the prevalence of infection in a particular region or country.

In Sierra Leone, the rural farmers are poor and live in deprived environments without proper hygiene and sanitation facilities (Koroma et al., 2010). These farmers and their children walk barefoot, dress half naked, and live together with animals on the same premises. At night, their livestock – goats, sheep, poultry – sleep either in the verandas, kitchens or near the houses, and their dogs often eat the feces of the children. Most rural communities lack pit latrines, and the inhabitants use nearby bushes for defecating. Their children sit, play or sleep on dusty grounds, and their primary schools are often found close to dustbins and most are without toilets. Rural children practice poor hygiene – they do not wash their hands after attending to nature, use contaminated household items, and eat contaminated food, exposing both children and adults to soil-transmitted helminth parasite infections (Yahya and Tukur, 2017). Most rural Sierra Leonean farmers and their children are unaware of and careless about the consequences of contaminated environments.

The women and children fetch water and firewood, fish in open-mined pits in swamps, clear debris in farms after ploughing and transplanting rice seedlings and growing vegetables. They empty the stool of infants and children under five years, which exposes people to Multiparasitism (Nkouayep et al., 2017), a concurrent infection with two or more parasite species (Khan et al., 2019). These daily activities highly expose rural vegetable farmers (who use untreated night soils as fertilizers) to soil-transmitted helminthic infections. Some farm families care directly for livestock – they take animals out for grazing and return them to living quarters, but seldom wash their hands after these activities. These farmers seldom deworm livestock (they are reared on the free-ranges systems) or clean the animal pens with disinfectant, nor do they provide any drinking water for the animals (exposing the animals to drinking muddy-dirty-stagnant waters). Hence, rural livestock with high helminth infections often experience miscarriages in Sierra Leone (Atanásio-Nhacumbe and Sitoe, 2019). Nevertheless, there is no scientific data on such an unfortunate situation; not even the Ministry of Agriculture nor the University pay attention to this group of people.

No wonder the Ministry of Health in Sierra Leone has vehemently campaigned for deworming school children in the urban settlements for the past decade, though such campaigns did not extend to reach the rural poor communities, or their schools and children who are more vulnerable than the urban children. In fact, any effective plan for reaching sustainable intervention and control of human intestinal parasites requires reliable information on the prevalence and intensity of soil-transmitted helminth infection from rural and urban settlements. But Sierra Leone lacks scientific data on the prevalence and intensity of soil-transmitted helminths in rural farming communities that show factual-information for better planning and strategy for controlling this deadly but neglected infection in the country. Soil-transmitted helminths cause loss of appetite, reduced nutritional intake, impaired physical fitness, diarrhea and dysentery (WHO, 2023). Ásbjörnsdóttir (2017) reported that soil-transmitted helminths (STH) are "endemic in 120 countries and are associated with substantial morbidity and loss of economic productivity"; while Masangcay et al. (2021) stated that malnutrition of micronutrients such as iron, Vitamin A, and zinc, is attributable to soil-transmitted helminths (STH) that disturbs the digestive functions.

Therefore, it is essential to investigate the intensity of the STH infections in rural farmers and their children and livestock to draw the attention of relevant stakeholders (including Ministry of Health and Sanitations and WHO) to explore areas to control the disease within the rural settlements in Sierra Leone. The study aims to describe and analyze the implications of the prevalence and intensity of soil-transmitted helminth infections in farmers in rural Sierra Leone. The study's specific objectives are to: 1) determine the prevalence of soil-transmitted helminths in farmers in Bo, Kailahun, and Koinadugu Districts of Sierra Leone; 2) determine the intensity of soil-transmitted helminths in farmers in the study area; 3) identify the effect of the prevalence and intensity on farm productivity in these districts, and 4) examine the implication of these on agricultural extension service provision in the selected districts.

Methods

The study was conducted in three districts – Koinadugu District in the North, Bo District in the South, and Kailahun District in the Eastern Regions of Sierra Leone. According to the STH prevalence maps, the entire population in the country is at risk of STH (Koroma et al., 2010). Those in five coastal districts, Koinadugu and part of Bo District, about 2.84 million people, (school age children and adults and pregnant women) are at high risk of STH infection (Bah et al., 2019). Koinadugu district continues to have moderate STH prevalence with high baseline prevalence greater than 75%, while a high proportion of households in Kailahun still practice open defecation. Another 2.6 million people in the remaining areas of the country are at moderate risk of STH infection, therefore justified for annual treatment to pre-school children, school age children and at-risk adults.

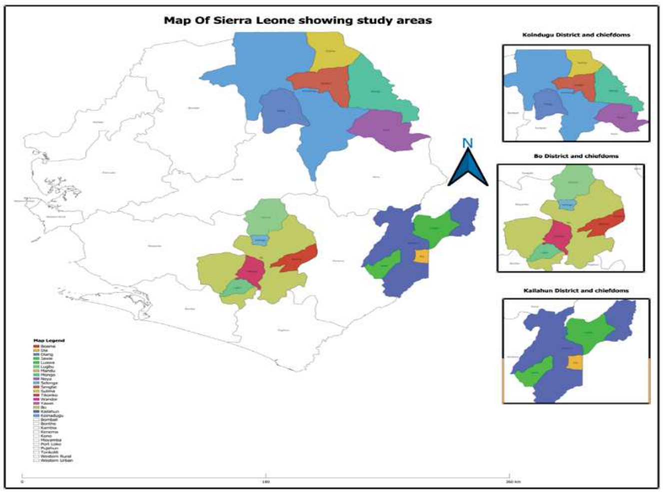

Fig. 1. Map of Sierra Leone showing study Districts and Chiefdoms

Source: Author's own elaboration.

These districts were selected using simple random sampling techniques. The main reasons for choosing each of these districts include their uniqueness. Koinadugu District is renowned for vegetable and livestock farming, Bo District is very prominent for diamond and sand mining, and Kailahun is paramount for tree crop production. Their populations are typically rural, with farming and livestock production as their main activities. These factors contribute to harboring and encouraging soil-transmitted helminth build-ups (Figure1).

The study adopted a cross-sectional design, examining stool from male and female farmers. The sampling technique was the stratified multistage cluster sampling technique. First, the names of all 14 districts were written on pieces of paper and placed in a black plastic bag. A simple random sampling was applied by blindly picking one paper from the black plastic bag. The researchers selected five chiefdoms from each district using simple random and purposive sampling techniques; each district (Total =15 Chiefdoms) and ten communities (totaling 150 precincts). A total of 625 individuals aged 18-65 (median: 52 years old) were registered and enrolled in the study. Among these enrollees, 339 (54.2%) were females, and 286 (45.8%) were males. In each selected district and community, the researchers held meetings with eligible individual farmers in court Berries, and those who consented to participate systematically underwent sample collection. All the participants provided stool samples for further analysis.

Table 1. The districts, chiefdoms, population, and sample size of farmers interviewed.

Districts	Chiefdoms	Population	Sample size
	Boama	5,300	61
	Tikonko	4,200	43
Bo	Valunia	3,500	55
	Selenga	1,200	38
	Lugbu	1,800	53
Total		**16,000**	**250**
	Yawei	2.200	33
	Jawie	3,100	46
Kailahun	Luawa	2,500	38
	Mandu	2,800	44
	Día	2,400	42
Total		**13,000**	**203**
	Diang	3,600	42
	Maini	2,300	37
Koinadugu	Senbge	2,400	38
	Neya	1,700	31
	Sulima	1,000	24
Total		**11,000**	**172**

Source: Field survey 2022.

Researchers gave a 60 mL plastic screw-cap vial to each participant who brought it back to the investigators with sample stool to examine whether eligible individuals had intestinal helminths. The researchers examined the specimen using Kato-Katz technique, a single thick smear technique using a 41.7 mg template (WHO, 2020). Qualified lab technicians from Government hospitals in each district examined the prepared samples (Kato-Katz slides). These technicians did so within one hour after the slide design for identification of hookworm eggs and subsequently (later the same day or the following day) for other STH eggs or larval (Strongyloides stercoralis) detection. Researchers used bright field microscopy (magnification × 100 or × 400) to identify and count all eggs (or larvae) in the prepared sample stools and expressed results as eggs or larvae per gram of feces (EPG or LPG) for the intensity of infection. Data collected were recorded into an SPSS 26 version for statistical analysis and used the SPSS Statistics "Crosstabs" procedure for calculating the proportion of individuals infected by a given parasite species (single infection) or by two or more helminth species (multiple conditions).

In terms of data analysis, SPSS Statistics "Descriptive" procedure was used to compute the intensity of diseases when the egg or larval counts were available as arithmetic means and estimated sampling fluctuations using the standard deviation (SD).

The Sierra Leone National Ethics Committee approved this study for Human Health Research, Ministry of Health in each district. The eligible population, individuals and livestock farmers willing to participate in the study, signed an informed consent form and each enrollee was assigned a code. Participants harboring any STH infection later received a 500 mg single-dose Albendazole in the framework of this study.

Results

Prevalence of STHs among farmers

Five species of soil-transmitted helminths (A. lumbricoides, T. trichiura, N. americanus, S. stercoralis and Tania spp.) were in the stool samples collected as part of this study. Of the 625 individuals who provided stool samples, Bo accounted for 160 (64.0%) positive samples, Koinadugu had 98 (56.9%) positive samples and Kailahun presented 105 (51.7%) positive cases. With varying significance levels of Bo (P=0.005), Koinadugu (P=0.005) and Kailahun (P=0.001). At district level, Soil-Transmitted Helminths (A. Lumbricoides) prevalence in Koinadugu District (22.1.0%) is higher than those in Bo District (18.0%) and Kailahun District (17.2%). For A. duodenale, prevalence was higher in Bo district (19%), followed by Koinadugu (16.9%) and Kailahun (11.8%). For S. Stercoralis, the margin was close among the districts of Kailahun (8.4%), Bo (8.0%) and Koinadugu (7.0%). Taenia spp. cases were 4.8%, 3.5% and 2.0% in Bo, Koinadugu and Kailahun districts, respectively.

At chiefdom levels, the prevalence of soil-transmitted helminths for Valunia (16.8%), Tikonko (14.0%), and Lugbu (13.2%) was higher than the prevalence for Selenga (7.2%). In Kailahun, most soil-transmitted helminths were 14.3% for Mandu, 11.8%, and 11.3% for Jawie and Día Chiefdoms, respectively. Yawei Chiefdom displayed the lowest STH prevalence. In the northern district of Koinadugu, Diang (16.3%), Maini (12.8%), and Neya (11.0) chiefdoms exhibited high STHs prevalence. Of the five STHs discovered in the stools of the farmers who participated in the study in Bo District, Ascaris lumbricoides are highly prevalent in Valunia (5.6%), Lugbu (5.2%), and Tikonko (5.2%), while T. trichiura (3.2%) was prevalent in Boama Chiefdom. In Kailahun District, A. lumbricoides is prevalent in Mandu (6.9%), Día (5.4%), and Jawie (5.4%). In Koinadugu District, Ascaris lumbricoides and American duodenale (7.0%, 7.0%) are prevalent in Diang, and Maini (5.8% and 4.1%) and Senbge (3.5%), and 2.3% respectively. T. trichuira (4.7%) is prevalent in Sulima Chiefdom, while T.spp. (1.2%) is prevalent in Neya Chiefdom. The distribution of these parasites in the selected districts was generally similar. Ascaris lumbricoides are highly prevalent in almost all the study sections.

Table 2. Prevalence of helminth parasites among farmers in three districts in Sierra Leone

Districts	Chiefdom	No. sample examined	No of positive samples	Ascaris Lumbricoides	S-Stercoralis	T- Trichuira	A Duodenale	Taenia. Spp
Bo	Boama	61	32(12.8)	10(4.0)	3(1.2)	8(3.2)	9(3.6)	2(0.8)
	Tikonko	43	35(14.0)	13(5.2)	6(2.4)	7(2.8)	8(3.2)	1(0.4)
	Valunia	55	42(16.8)	14(5.6)	7(2.8)	7(2.8)	12(4.8)	2(0.8)
	Selenga	38	18(7.2)	12(4.8)	2(0.8)	3(1.2)	1(0.4)	0(0.0)
	Lugbu	53	33(13.2)	13(5.2)	6(1.6)	4(1.6)	9(3.6)	1(0.4)
	Total	250	**160(64.0)**	**62(18.0)**	**24(8.0)**	**29(10.8)**	**39(19.2)**	**6(4.8)**
	p value	< 0.001	**0.005**	**0.018**	**<0.001**	**< 0.001**	**<0.001**	**< 0.001**
Kailahun	Yawei	33	12(5.9)	5(2.5)	1(0.5)	2(1.0)	4(2.0)	0(0.0)
	Jawie	46	24(11.8)	11(5.4)	5(2.5)	4(2.0)	2(1.0)	2(1.0)
	Luawa	38	17(8.4)	8(3.9)	3(1.5)	2(1.0)	3(1.5)	1(0.5)
	Mandu	44	29(14.3)	14(6.9)	4(2.0)	3(1.5)	7(3.4)	1(0.5)
	Dia	42	23(11.3)	11(5.4)	4(2.0)	3(1.5)	5(2.5)	0(0.0)
	Total	**203**	**105(51.7)**	**49(17.2)**	**17(8.4)**	**14(6.9)**	**21(11.8)**	**4(2.0)**
	p value	**< 0.001**	**0.001**	**< 0.001**	**0.005**	**0.005**	**0.002**	**0.009**
Koinadugu	Diang	42	28(16.3)	12(7.0)	1(0.6)	1(0.6)	12(7.0)	2(1.2)
	Maini	37	22(12.8)	10(5.8)	2(1.2)	2(1.2)	7(4.1)	1(0.6)
	Senbge	38	14(8.1)	6(3.5)	3(1.7)	1(0.6)	4(2.3)	0(0.0)
	Neya	31	19(11.0)	7(4.1)	3(1.7)	1(0.6)	6(3.5)	2(1.2)
	Sulima	24	15(8.7)	3(1.7)	3(1.7)	8(4.7)	0(0.0)	1(0.6)
	Total	**172**	**98(56.9)**	**38(22.1)**	**12(7.0)**	**13(7.6)**	**29(16.9)**	**6(3.5)**
	p value	**< 0.001**	**0.005**	**<0.001**	**< 0.001**	**0.005**	**< 0.001**	**0.005**

Statistically significant; p < 0.05; Mean (SD)

Source: Field survey 2022.

The intensity of STHs infection in farmers

The intensity of the STH infection ranged between 1412.2 and 5233EPG (mean: 11,234.21; SD: 14,254.51) for Ascaris lumbricoides, 103.11 and 447.12EPG (mean: 321.33; SD 2312.02). for S. stercoralis, 45.26 and 23.03EPG (mean: 213.07; SD: 102.11) for T trichiura with 1.1 and 6.1EPG (means: 10.14; SD: 3.32) for Taenia spp and 11.67 and 33.01EPG (mean: 6.13; SD:1.85) for A duodenale. Also 2.32 and 34.22EPG (mean: 24.24; SD:18.72) for Tania. Spp. 1.35 and 43.11 EPGepg (mean: 3.12; SD:2.43). Table 2 reveals the arithmetic means (with standard deviation) intensity of infection for each parasite species. The mean egg or larva count was quite variable between chiefdoms within the districts. In Bo District, S. stercoralis, T. trichiura, and A. duodenale and Taenia spp. (p<0.001), but different for A. lumbricoides (<0.018). For Kailahun District, district, S. stercoralis and T. trichiura (p=0.005) differ from A. lumbricoides (p<0.001) and A. duodenale (p = 0.002). For Koinadugu District, A. lumbricoides, S. stercoralis and A. duodenale (p<0.001) differ from T. trichiura and T. spp. (p=0.005).

Table 3. Intensity of STH infection in farmers in the selected districts of Sierra Leone

Districts	Chiefdom	No. sample examined	Mean A-Lumbricoides EPG(SD)	Mean S-Stercoralis EPG(SD)	Mean T-Trichiura EPG(SD)	Mean Duodenale Lpg(SD)	Mean Taenia. Spp EPG(SD)
Bo	Boama	61	5233.14(14254.51)	447.12(2312.02)	23.12(223,34)	33.01(1.85)	6.09(93.32)
	Tikonko	43	3543.24(15345.42)	311.22(2214.03)	26.23(132.12)	23.12(2.11)	5.5(2,54)
	Valunia	55	4254.17(23341.53)	414.31(3241.12)	37.02(146.28)	14.35(2.43)	6.1(3.32)
	Selenga	38	3182.32(12321.34)	2303.23(123.04)	23.11(321.38)	12.36(1.43)	3.1(0.21)
	Lugbu	53	4332.15(32132.42)	413.12(4321.21)	34.24(423.09)	13.53(2.12)	4.1(41.32)
Kailahun	Yawei	33	3671.23(12325.12)	321.14(1421.24)	31.11(187.21)	14.2(3.31)	2.02(18.72)
	Jawie	46	424.87(22654.32)	432.18(213.14)	45.26(213.07)	24.5(1.21)	4.14(7.16)
	Luawa	38	5431.73(13123.43)	425.25(123.05)	23.03(102.11)	24.1(2.32)	4.2(25.24)
	Mandu	44	329.15(14234.12)	210.98(234.21)	34.23(192.22)	22.2(3.21)	3.2(45.23)
	Día	42	323.34(12123.23)	121.29(187.23)	32.11(203.26)	22.1(2.12)	2.5(12.32)
	Diang	42	2823.12(11214.12)	124.86(213.22)	41.24(112.41)	12.3(4.11)	1.4(22.24)
	Maini	37	2213.23(12231.03)	227.56(321.21)	32.22(214.23)	14.12(2.14)	4.2(19.24)
Koinadugu	Senbge	38	1412.21(11234.21)	116.4(134.24)	23.36(123.12)	13.11(3.12)	2.1(14.23)
	Neya	31	1923.11(12112.04)	114.22(314.32)	32.22(231.17)	12.03(2.33)	1.2(9.14)
	Sulima	24	1526.02(13532.12)	103.11(321.33)	31.23(113.46)	11.67(6,13)	1.1(10.14)

EPG = eggs per gram of stool; LPG = larvae per gram of stool; SD = standard deviation

Source: Field survey, 2022.

Levels of the effect of the prevalence and intensity of STH on farm productivity

The result showed that 97.9% of the farmers indicate that high STH medication expenses halt most farming activities, and 96.0% say STH resistance in the various species causes persistent unhealthy conditions in the farmers. Furthermore, 93.9% of the participants say that STH-resistance causes constant unhealthy conditions in the farmers, while 91.8% say the STH prevalence and intensity burdened farmers. Moreover, 89.3% of the farmers said that multiple STH infections bring repeated farm economic losses, and 76.6% say that high STH-medication expenses halt farming activities in most communities. In some cases, the STH-anemia conditions reduce the available community-labor force. Only 64.2% of the farmers pointed out that STH infections impair growth and physical development in farmers. (Table 4)

When further asked to rate the level of STH infections on farm productivity, 40.6% of the farmers ordered the prevalence and intensity of STH burden on farmers as very high, and 32.2% rated multiple STH medication expenses as a reason halting most community-farming activities as very high. STH-anemia conditions reduce the available community-labor force (32.4%), and STH-induced malnourishment reduces the farm population (32.5%) were rated moderately. Furthermore, STH resistance causes persistent unhealthy conditions in the farmers (33.9%), STH infections impair growth, and physical development in farm families (40.2%) was rated moderate. and 25.4% of the farmers' rated worm-induced malnourishment reduces the farm population also as moderate. (Table 4)

Table 4. Levels of the effect of the prevalence and intensity of STH on farm productivity

Effects of prevalence and intensity of STHs	No	Low	Moderate	High	Very High
STH prevalence and intensity create burden on farmers	574(91.8)	123(19.7)	138(22.1)	254(40.6)	110(17.6)
STH-anemic conditions reduce available community-labor force	479(76.6)	156(25.4)	199(32.4)	138(22.4)	122(19.8)
Worm-induced malnourishment reduces farm population	587(93.9)	103(16.5)	203(32.5)	113(18.1)	206(33.0)
Multiple STH-infections bring repeated farm economic losses	558(89.3)	116(18.6)	104(16.6)	201(32.2)	204(32.6)
High-STH-medication expenses halt most community-farming activities	612(97.9)	103(165.5)	98(15.7)	198(31.7)	226(36.2)
STH-resistance causes persistent unhealthy conditions in the farmers	600(96.0)	101(16.2)	212(33.9)	208(33.3)	104(16.6)
STH-infections impair growth and physical development in farm families	401(64.2)	109(20.8)	211(40.2)	103(19.6)	102(19.4)

Frequency (percentages).

Source: Field survey 2022.

Perceptions of farmers and extension workers on the implication of STHs on agricultural service provisions and the livelihood of the farmers was also surveyed. The farmers perceived that the effects from STH infections have significantly impacted the extension delivery services and the livelihood of the farmers in their communities. Table 5 indicates that 40.0% of the farmers expressed that STH infection is causing poverty among farmers, reducing food productivity at community levels (35.2%), restraining youths from adopting agricultural extension innovations (26.9%), and forcing farmers not to cooperate with extension agents (26.3%). Furthermore, the infection causes farmers to divert agricultural innovations (24.8%), while most farmers do not use farm inputs from agricultural extension agents.

Table 5. Distribution of farmers and extension workers on the extent of implications of STHs on service provision and livelihoods

Perception on implications STHs	**Very great extent**	**Great extent**	**Some extent**	**No extent**	**Can't know**
Perception of farmers (n=505)					
Sick farmers cannot attend extension meetings	111(22.0)	102(20)	113(22.4)	110(22)	69(13.7)
Farmers affected accept but do not adopt innovations	122(24.2)	113(22)	119(23.6)	104(21)	47(9.3)
Farmers do not cooperate with extension agents	133(26.3)	123(24)	111(22)	102(20)	36(7.1)
Farmers diverse the use of farm innovations like seeds	125(24.8)	115(23)	116(23)	117(23)	32(6.3)
Youths restrain from adopting extension innovations	136(26.9)	112(22)	132(26.1)	102(20)	23(4.6)
STH infections have reduced community-farm productivity	178(35.2)	121(23)	98(19.4)	85(17)	23(4.6)
STH infections have caused poverty	202(40)	214(42)	64(12.7)	21(4.2)	4(0.8)
Perception of extension workers (n = 120)					
Infected farmers consume agricultural seed inputs	78(65)	23(19)	15(12.5)	3(2.5)	1(0.8)
Number of agricultural innovation adoption has reduced	77(64.2)	33(28)	10(8.33)	0(0)	0(0)
Infected farmers cannot disseminate innovation	59(49.2)	33(28)	23(19.2)	3(2.5)	2(1.7)
Farmers' household expenditure has increased	49(40.8)	44(37)	24(20)	82(1.7)	1(0.8)

Frequency (percentages).

Source: Field survey 2022.

To a great extent, the extension agents also perceive that STH-infected farmers consume agricultural farm seed inputs (65.0%). The number of agricultural innovation adopters is drastically reduced (64.2%), while the infected farmers no longer disseminate agricultural innovations (49.2%) which has increased the farm household expenditure (40.8%), affecting the extension delivery and the farmer's livelihoods.

Discussion

The overall prevalence of the different STH species follows very similar trends. The finding is in line with Means et al. (2018); Oswald et al. (2019). However, the results in this study were higher than those found by the authors. Furthermore, significant differences in the STH prevalence existed between the selected chiefdoms (Table 2), which supports the findings of WHO (2017). The high prevalence recorded in the various chiefdoms is ascribed to poor nutrition (starvation), management practices of feces (lack of toilets), and frequent human exposure to contaminated soils during farming activities.

Kailahun District shares a similar culture, but their farming patterns differ significantly, which might be responsible for the predominant occurrence of the different parasites among the farmers. The intensity of infections and the values recorded in our study were generally from light intensity to high, based on the WHO classification (WHO, 2020). The observed outcome is actual because participants in this study were either adults or young adults. A close look at some of the behavioral habits of the farmers in these three districts and the fifteen chiefdoms concerning personal hygiene reveals that a good number of them are highly predisposed to infection with intestinal helminths. Most of the farmers in Bo District are upland rice farmers, who primarily farm very close to their communities, without proper feces disposal. Their farming patterns also involve playing with soil and shrubs; these farmers seldom wear protective clothing during their farming operations. In addition to farming, most are sand and illicit miners—the women fish in the stagnant pits and streams, harboring STH eggs and larvae. In Kailahun District, most of the farmers are tree crop farmers, who use the local processing techniques, sitting on the ground, peeling, packing, and transporting the products. During the harvesting period, most farmers walk barefooted, half- nakedly dressed, with no protective gear, a situation that exposes farmers to STH infections.

Epidemiological surveys show that poor sanitary conditions such as defecation and fecal contamination of water bodies are the most critical factors leading to intestinal infestation (Benjamin-Chung et al., 2020). Similarly, in Koinadugu, most farmers are vegetable growers who cultivate their crops in lowland ecology during the dry seasons and upland during rainy seasons. These farmers use night soils as fertilizers for the vegetables they produce. Like those in Kailahun and Bo districts, farmers in Koinadugu do not use protective clothing when at work. They mix the night and garden soils using their bare hands thereby contacting STH eggs or larvae.

The effect of STH infections and levels of impacts on farm productivity

Infections with parasitic nematodes restrict the welfare of the farmers and farm productivity, as these farmers rely heavily on administering anthelmintic drugs, as Taiwo et al. (2017) discovered in their study. The results showed that 97.9% of the farmers expressed that high STH medication expenses halt most farming activities, and 96.0% say that STH resistance in the various species causes persistent unhealthy conditions in the farmers (Table 4). These findings align with Campbell et al. (2018) that soil-transmitted parasites are prevalent and cause different disease conditions among poor rural dwellers in developing countries (Ayele et al.2019). Helminth infections are challenging to cure – the drugs are costly and scarce. Some commercially available drugs include benzimidazole, imidazothiazole and macrocyclic lactone groups (Gyang et al., 2019. This high cost is a burden on farm families. Some farmers take loans from money lenders to pay medical bills, reducing the area cultivated annually.

Furthermore, 93.9% of the participants say that STH-resistance causes constant unhealthy conditions in the farmers, while and 91.8% say that the STH prevalence and intensity burdened farmers. The findings agree with Darlan et al. (2018) that the cost of medical treatment for STH infections has a tremendous negative impact on farmers in the rural areas of West Africa. Such high cost affects the economic earning capacity of the farmers, making them incapable of farming anymore. As the number of farmers affected by STH infections increases, the farming population reduces. STH illnesses cease farmers' abilities to innovate, experiment, and implement changes and to acquire technical pieces of information through extension activities. Also, absenteeism from work due to frequent illness and/or morbidity (and eventual death); family time diverted to caring for the sick. Healthcare expenses may consume resources useful for improved seeds, fertilizers, equipment, and other farm inputs that can improve farm productivity. Sick family members seldom adopt labor-intensive techniques, negatively affecting farm productivity.

Furthermore, the impact of ill health results in a decline in household income, food insecurity and severe deteriorated household livelihood (Bah, et al., 2919). Farmers have accumulated technical and managerial skills that are not easily substitutable through the labor market or family and other social connections; their inability to perform agricultural activities because of STH infection significantly negatively impacts overall efficiency (Koroma et al., 2010). Unhealthy farmers deteriorate physically and mentally, reducing their concentration on farm activities, while increasing medical expenditure and taking loans, thus becoming indebted. Most rural farmers do not have accumulated money/income, especially from agriculture; they use their physical power very heavily for the commencement of the farming operations during the cropping times.

Conclusions

STH prevalence is relatively high among the farmers in selected chiefdoms in the study area. Farmers were observed to have moderate and high-risk levels and farmers harboring the parasites are likely to constitute potential parasite reservoirs and sources of dissemination and persistence of these infections. Moreover, the most infected farmers are those engaged in tree crop production – rice and vegetable farming in Kailahun, Koinadugu and Bo Districts. Most farmers' main form of parasite control is a small number of anthelmintic compounds, mainly bought from quack drug peddlers. These findings underscore the need for robust research into the health effects of STH in farm families. Hopefully, the findings presented here will help encourage future investigations to consider the three surveyed districts, and to also consider the social and geographical differences across the region and country during the course of such investigations.

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Changes in the Vegetable Oil Market, with Particular Emphasis on Market Instability in Relation to the War in Ukraine

Abstract. In the 21st century, the global production and consumption of oilseeds and their processing products are growing dynamically as a result of the globally growing demand for food and renewable energy. Globally, supply and demand factors have changed the edible vegetable oils industry. The production of vegetable oils is characterized by one of the highest dynamics among all agricultural raw materials, which results from the growing demand for vegetable oils for food, industrial purposes and the growing demand for protein feed. The cultivation of oilseeds plays an important role in Polish agriculture. On an industrial scale, the production of rapeseed oil dominates in Poland, and is a strategic product of the Polish agri-food sector. Sunflower and soybean oils are also of market importance. The scale of crude rapeseed oil production ranks Poland third in the European Union (after Germany and France) and sixth in the world. The country's share in EU rapeseed oil production is about 13%. Poland, despite the dynamic development of rapeseed production and processing which took place after 2004, has low self-sufficiency in the field of oilseed products, especially low in the field of oilseed meals (self-sufficiency at the average level of approx. 43% in 2018-2020) and oils vegetable crops (self-sufficiency at the average level of approx. 63%); therefore, it remains a permanent, large net importer.

Key words: edible oils, rapeseed oil, sunflower oil, oils market, edible oils market, vegetable oils, war in Ukraine

JEL Classification: D40, Q02

Introduction

Oilseeds play a significant role in the world's agriculture, food economy and processing industries. They are the raw material for production of consumer and technical fats, they are a source of food and feed protein, and some of them, such as cotton and linen, also provide plant fiber (Rosiak, 2014). They are an essential element of the agri-food sector. And the industry itself, as noted by Drejerska and Fiore (2022), as part of the agri-food sector, plays a crucial role in the global economy. It is directly related to the livelihoods of almost eight billion people.

Consequently, the issue of the current situation in the market of edible vegetable oils is an important topic. In the 21st century, the global production and consumption of oilseeds and their processing products (vegetable oils and oilseed meals) is dynamically growing, as a result of the growing demand for food and renewable energy on a global scale. At the same time, the growth rate varies regionally (Rosiak, 2018, 2019). This increase is due to the growing interest in using vegetable oils for both food and industrial purposes.

Vegetable oils are fats of vegetable origin that have a liquid consistency at room temperature (an exception is, for example, coconut oil). In chemical terms, vegetable oils are triglycerides; an ester bond connects three molecules of fatty acids with a molecule of

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glycerol. Humans have used vegetable fats for years. These fats have found application in many areas of life, e.g., in nutrition, dietetics, medicine, cosmetology, tribology and as alternative fuels (Szczypska, 2019, Zielińska and Nowak, 2014). Vegetable oils are noble natural raw materials that are used in many ways. The first is human nutrition, for whom rapeseed and sunflower oils have well-established nutritional properties (Pilorgé and Muel 2016). As indicated in the literature, commonly used vegetable oils – sunflower oil, soybean oil, low erucic rapeseed oil, and olive oil – have the highest nutritional value in everyday use (Goryńska-Goldmann, 2005). Edible vegetable oils are versatile and can be used in products such as fried foods, mayonnaises, margarines, shortenings, pharmaceuticals, and biofuels. Typical cooking oils include soybean, canola, palm, corn, coconut, cottonseed, olive, and sunflower. The choice of edible vegetable oil for a particular application depends on the price and the fatty acid profile, which indicates the features and benefits of the oil. (Smith, 2005; Shahidi, 2005; Parcell et al., 2018).

Globally, supply and demand factors have transformed the edible vegetable oil industry (Parcell et al., 2018). The production of vegetable oils is characterized by one of the highest dynamics among all agricultural raw materials, which results from the growing demand for vegetable oils for food and industrial purposes and the increasing demand for protein feed (Boczar, 2012). The market for vegetable oils is believed to be saturated regarding household demand for these oils. The low-income elasticity of demand for vegetable fats also evidences saturation. According to various authors, this value was at the level of 0.1 and lower. Such a low level of this ratio indicates that the needs for vegetable fats in households are primarily satisfied and that no significant increase in the consumption of these products is expected due to an increase in income. (Rosiak 2006, Gulbicka, Kwasek 2000; 2001; 2006; Laskowski 2014; Boczar, Goryńska-Goldmann, 2005; Boczar, Błażejczyk-Majka, 2018). In recent years, a substantial proportion of edible oils has been sunflower oil due to its high nutritional quality and desirable industrial functionality (Domínguez Brando and Sarquis, 2012). Historically, sunflower oil has been considered a premium oil, with average prices generally significantly higher than soybean and rapeseed oil until 2016. (Oil World, 2019). Rapeseed oil is primarily characterized by a favorable composition of fatty acids – the lowest content of saturated acids and the highest content of unsaturated acids, including n-3 acids (Krygier, 2009).

Sunflower cultivation is currently limited to southern Europe and Central/Eastern Europe, mainly due to temperature (Debaeke et al. 2017). Sunflower is produced on a large scale in a limited number of countries, with two-thirds of production concentrated in Europe, including Ukraine and Russia, and in the Trakia region of Turkey. Other major producing countries include Argentina, China, the United States and Southeast Africa (South Africa, Tanzania, Uganda, and Zambia) (Pilorgé, 2020). It should be noted that Russia and Ukraine have a 50% share of the global sunflower oil market and are at the forefront of rapeseed oil supplies (Zavorotniy and Bilyk, 2017, Kuts and Makarchuk, 2020, FAO, 2020). Currently, rapeseed ranks second in the world in the cultivation of oilseeds, after soybean. Regarding the amount of oil produced, it ranks third, after palmitic and soybean oil. The largest world producer of rapeseed is the European Union. Its crops account for 34% of global production, which is 19-20 million tons per year. China, Canada, India, Ukraine, and Australia follow it. Compared to other European Union countries, Poland ranks third, after Germany and France (Gugała et al. 2014).

In the context of the edible oils market, it should be noted that Ukraine is also one of the five largest global exporters of rapeseed, sunflower oil, and sunflower meal. It should be noted that the supplies of sunflower oil from Ukraine have practically stalled due to logistical problems related to the armed conflict. And given the significant share of Ukrainian exports in the global oil market, any supply disruption will have serious consequences for oil importers. This means that the effects of the conflict will extend beyond the sunflower oil sector, with a temporary impact on the markets of other vegetable oils. The OECD-FAO agricultural forecast for 2019-2028 believes that vegetable oil prices should increase (OECD-FAO, 2019; Zolotnytska, Kowalczyk, 2022).

The cultivation of oilseeds plays a vital role in Polish agriculture. On an industrial scale, the production of rapeseed oil dominates in Poland, which is a strategic product of the Polish agri-food sector. Sunflower and soybean oils are also of market importance. The crude rapeseed oil production scale ranks Poland third in the European Union (after Germany and France) and sixth in the world. The country's share in EU rapeseed oil production is around 13% (Polish Association of Oil Producers, 2021). Poland, despite the dynamic development of rapeseed production and processing which took place after entry to the EU in 2004, has low self-sufficiency in the field of oilseed products, especially low in oilseed meals (self-sufficiency at the average level of approx. 43% in 2018-2020) and oils crops (self-sufficiency on average around 63%). Therefore, it remains a permanent, sizeable net importer (Kapusta, 2022).

Material and methods

The purpose of this article was to present the changes that have taken place in the edible vegetable oils market in recent years, with particular emphasis on trade between the European Union and Poland with Ukraine. Attention was paid to the transformation of the market as a result of the war in Ukraine. These changes were assessed based on monthly data for selected periods. To present the general situation on the vegetable oil market, data from IEGRiGŻ PIB reports from 2015-2022, and Euromonitor International 2022 and Oil World data from 2019-2022 were used. To assess the impact of the war in Ukraine on the situation in the EU and Polish markets, data from the European Commission's data bank, i.e., Oilseeds and Protein Crops Trade, Directorate-General for Agriculture and Rural Development, section Trade, were used. To illustrate these changes, monthly data on the level of imports of selected oils by Poland and the EU from Ukraine were used, as well as monthly data showing the export of rapeseed oil by Poland from Ukraine. Bearing in mind the significant importance of Ukraine in the production of oilseeds and the oil itself, the import of two oils by the EU with the most significant importance in the trade relationship between Ukraine and the EU and Poland, i.e., rapeseed oil and sunflower oil, was analyzed.

The data analysis process in this study entails utilizing monthly data for selected periods to assess the changes in the vegetable oil market. The following steps were undertaken to conduct the analysis:

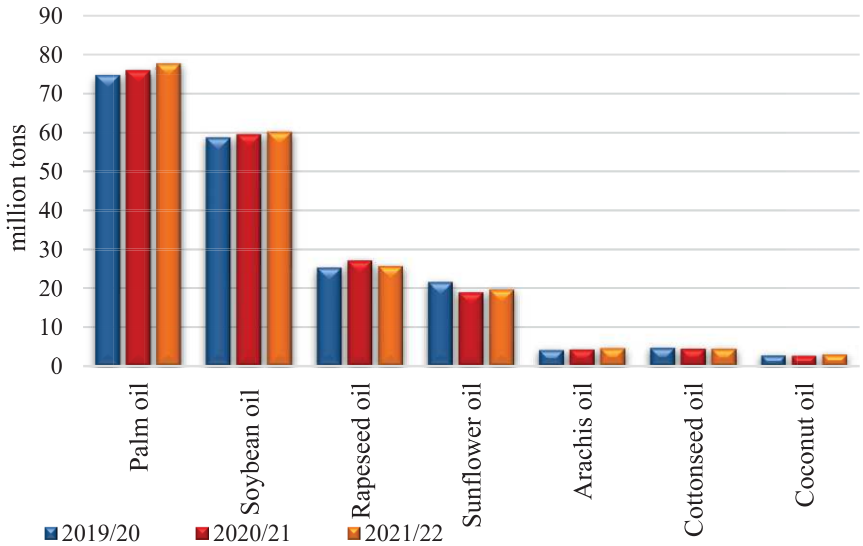
1. Data collection: Monthly data pertaining to the import of specific oils from Ukraine by Poland and the European Union (EU), as well as the export of rapeseed oil from Poland to Ukraine, were gathered. These data points were sourced from the aforementioned databases.
2. Data cleaning and preparation: The collected data were meticulously scrutinized for inconsistencies, missing values, and outliers. Necessary corrections and adjustments were applied to ensure data integrity and accuracy.

3. Data transformation: The collected monthly data was organized and transformed into a format suitable for analysis. This involved structuring the data as a time series, with each observation representing a distinct month within the chosen periods.
4. Descriptive analysis: Descriptive statistics, encompassing measures of central tendency and variability, were computed to summarize the data. These statistics provided a comprehensive overview of the distribution and characteristics of the imported and exported oils.
5. Interpretation of results and conclusion: The analyzed data and statistical findings were interpreted to comprehend the implications of the observed changes in the vegetable oil market. The results were meticulously analyzed within the context of the war in Ukraine, taking into consideration its potential influence on market instability.

Results

Changes in the vegetable oils market

According to the Oil World forecast from May 2022 and the IERiGŻ, production of 8 main vegetable oils (palm, soybean, rapeseed, sunflower, cotton, peanut, palm kernel and coconut) will amount to 203.5 million tons and will be 1.4% higher than in the previous season, which is the highest level in history (IERiGŻ, 2022).



* 2021/2022 Oil World estimate

Fig. 1. World production of vegetable oils (in million tons)

Source: Authors' own study based on IEGRiGŻ National Research Institute and Oil World data.

As indicated by the data analysis, palm oil production has been most important in the global production of edible oils over the last few years. In the marketing years 2021/22, it reached the level of 77.64 million tons and was thus 17.54 million tons higher than in the case of soybean oil, which ranked second in the world ranking of vegetable oil production (Figure 1). Rapeseed oil production ranked third. It should be noted, however, that despite the significant importance of this oil in the global production of edible oils, this level is lower than in the previous two. In the marketing years 2019/20 - 2021/22, this production amounted to 26.04 million tons on average per year.

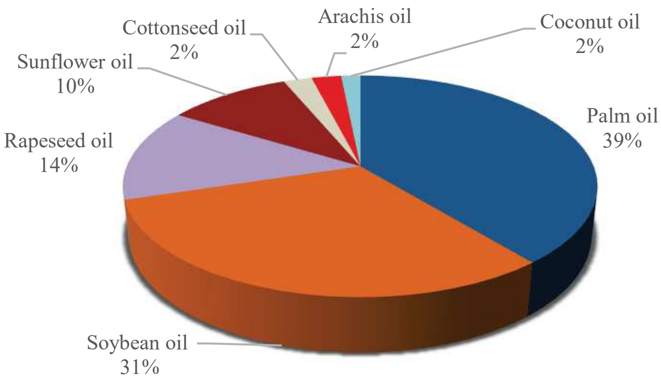


Fig. 2. The structure of vegetable oil consumption in the world (%)
Source: IERiGŻ NRI based on Oil World data.

Table 1. Foreign trade in oil products in Poland (in thousands of tons)

	2015	2016	2017	2018	2019	2020	2021 a)	2022 b)
Export								
Vegetable oils	**539,0**	**473,4**	**178,7**	**136,5**	**185,5**	**232,4**	**286,8**	**290,0**
rapeseed oil	526,1	449,7	141,0	82,4	98,3	84,7	109,8	115,0
Import								
Vegetable oils	**551,8**	**635,4**	**751,7**	**804,5**	**932,1**	**1078,7**	**1033,3**	**870,0**
palm oil	223,2	240,6	252,7	265,9	283,3	251,9	247,7	250,0
sunflower oil	55,1	51,2	150,3	154,9	209,4	301,7	207,8	180,0
soybean oil	93,5	107,0	116,5	133,6	193,3	228,8	226,9	230,0
rapeseed oil	122,4	147,2	163,2	181,4	178,4	203,5	243,0	210,0
Turnover balance								
Vegetable oils	**-12,8**	**-162,0**	**-573,0**	**-668,0**	**-746,6**	**-846,3**	**-746,5**	**-580,0**
rapeseed oil	403,7	302,5	-22,2	-99,0	-80,1	-118,8	-133,2	-95,0

Source: Authors' own study based on European Commission data.

Similar trends can be seen in the case of vegetable oil consumption. The analysis of their consumption structure indicated that the most frequently consumed vegetable oil in the world is palm oil (37%) (Figure 2). The second and third place was taken by soybean oil (30%) and rapeseed oil (13%). It should be noted that this list includes oils consumed directly by households and those consumed by purchasing products that contain the above oils.

In 2015-2022, the Polish export of vegetable oils was characterized by significant variability in individual years. This export mainly concerned rapeseed oil (Table 1). The situation related to the import of vegetable oils was different, where an upward trend is visible in the years 2015-2022. In 2021, the import of vegetable oils was almost twice as high. The most significant increase concerned imports of sunflower oil (almost four times). This contributed to the negative balance of foreign trade in vegetable oils, which increased over 58 times in 2015-2021. A slightly different situation occurred in 2022, where the import of oils, mainly sunflower and rapeseed, decreased significantly. In this case, the effects of the war can be seen, i.e., a decrease in imports from Ukraine and Russia, the main producers of sunflower and rapeseed oil.

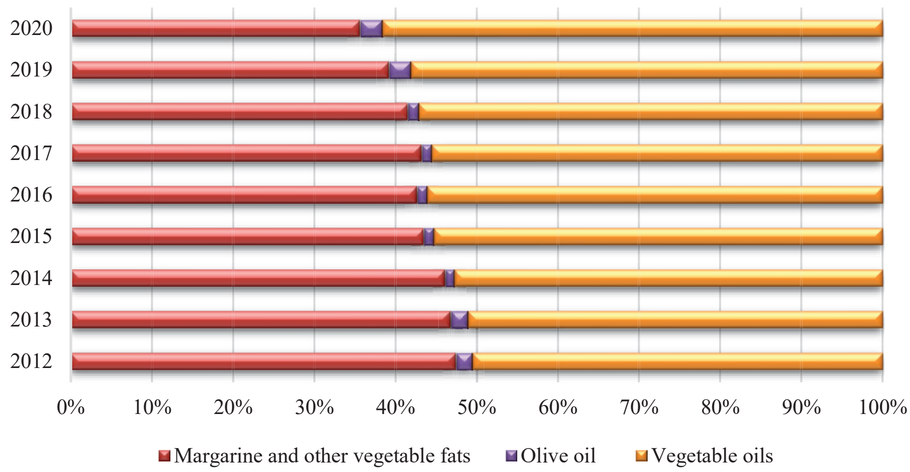


Fig. 3. Average monthly consumption of fats in households in kg/l per capita (according to family budget surveys) in Poland

Source: IERiGŻ NRI based on data from the Central Statistical Office.

As suggested by the above data, despite the dynamic development of rapeseed production and processing, Poland has low self-sufficiency in producing vegetable oils (approx. 57-64%) and therefore remains a permanent, sizeable net importer of them. This is due to the limited possibilities of developing the production of oilseeds and the growing demand for vegetable oils (including technical oils due to the development of biofuel production). It should be noted that since 2017 Poland has become a net importer of rapeseed oil, despite the growing production of rapeseed. The analysis of the average monthly consumption of fats in households in kg/l per capita showed that in the years 2015-2020 the share of vegetable oils was gradually increasing. A similar situation occurred in the case of olive oil. However, the share of margarine and other vegetable fats decreased (Figure 3).

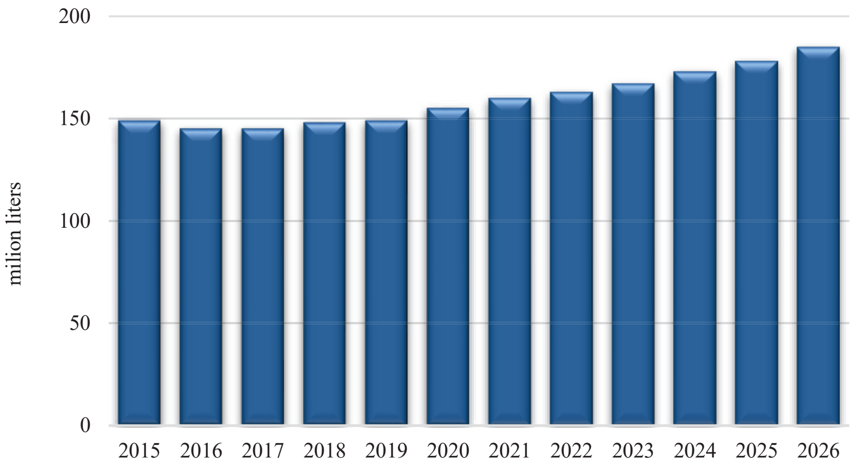


Fig. 4. Forecasts of retail sales of vegetable edible oils in Poland

Source: Euromonitor International 2022.

Forecasts provided by "Euromonitor International" indicate that the volume of retail sales of edible oils in Poland will gradually increase in the coming years. (Figure 4).

The impact of the war in Ukraine on the market of vegetable oils

Due to the significant importance of Ukraine in the supply of vegetable oils, changes in the export of three vegetable oils of the greatest importance in the trade relationship between Ukraine and the EU and Poland were analyzed. It should be noted that significant differences in individual months characterize imports of rapeseed oil by the EU from Ukraine. The peak for imports, in this case, falls in August-November. The analysis of data from the 2019/2020-2022/2023 marketing years showed that 2021/2022 turned out to be a record year in this period, where the import level of rapeseed oil amounted to 120,831 t and was more than twice as high as in the previous year (Figure 5). It should be noted, however, that this situation changed dramatically after the outbreak of the war in Ukraine. With the escalation of the conflict, the amount of rapeseed oil imported by the EU from Ukraine was successively decreasing. In June 2022, the amount of imported rapeseed oil was three times lower than in the previous year. A similar situation occurred in the following months, July 2022 - November 2023. In these months, the level of imports was, on average, five times lower than in the corresponding months of the previous year. This situation, among others, should be considered, in the problems in exports from Ukraine resulting from the conflict and the decline in production caused by the same factor.

Despite the numerous problems in the export of sunflower oil from Ukraine after Russia's aggression, this disturbance was short-lived in the case of the European Union. The decrease in EU sunflower oil imports from Ukraine in the 2021/2022 marketing years fell in March - May 2022, and then these imports stabilized (Figure 6). It should be noted that despite the challenging market situation, the level of imports of sunflower oil by the EU from Ukraine in June 2022 - December 2022 was higher than in the same months in 2021.

The situation in January 2023 was different. When this import was more than two times lower than in January 2022 and, on average, by 40% compared to January 2021, this loss may result from a decrease in the sunflower harvest in 2022 resulting from the decline in crops. It should be noted that sunflower production in Ukraine is located mainly in the eastern part of the country, i.e., the area of increased fighting. It can therefore be expected that in the coming months, the trend observed in January 2023 may continue.

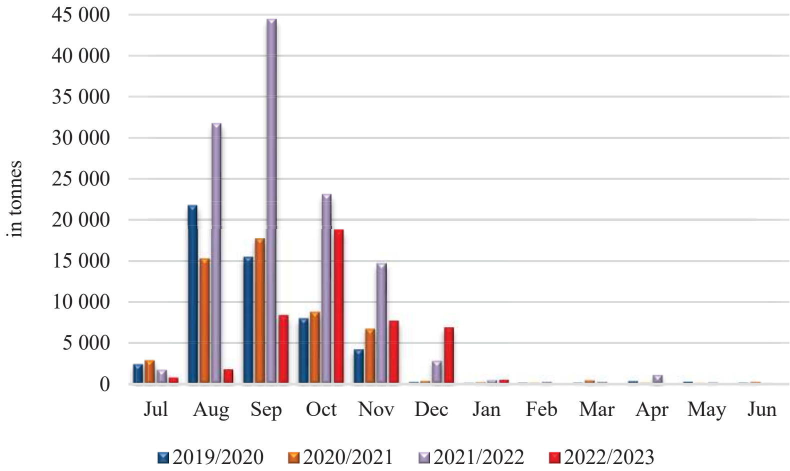


Fig. 5. Imports rapeseed oil by the EU from Ukraine (in tons)

Source: Authors' own study based on European Commission data.

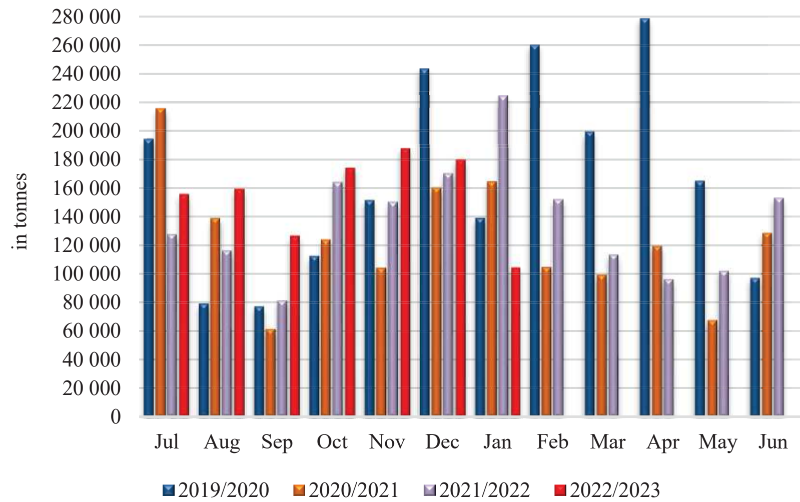


Fig. 6. Imports sunflower oil by the EU from Ukraine (in tons)

Source: Authors' own study based on European Commission data.

The analysis of the level of imports of rapeseed oil by Poland from Ukraine in the last three marketing years showed that in July - September 2022, the level of imports of this oil decreased significantly compared to previous years in these months. Compared to the same period in 2021, there was a decrease of over 50% (Figure 7).

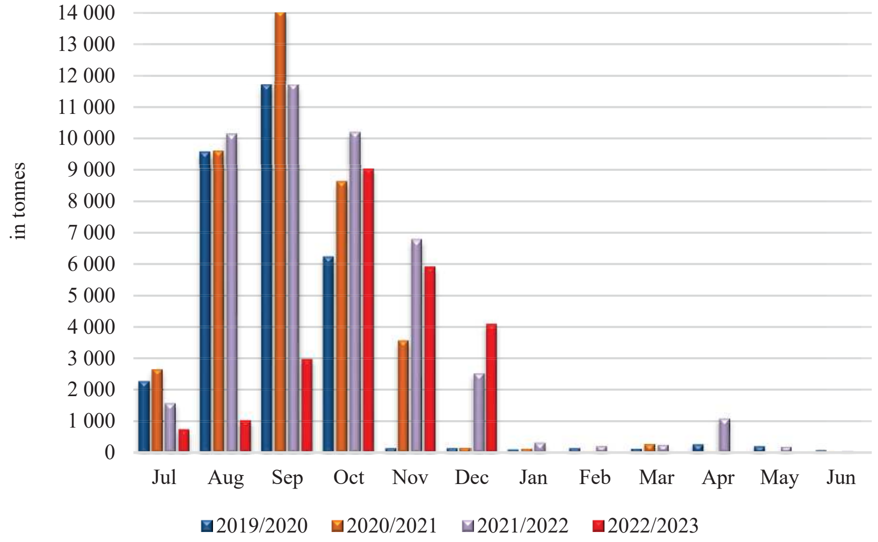


Fig. 7. Imports rapeseed oil through Poland from Ukraine (in tons)

Source: Authors' own study based on European Commission data.

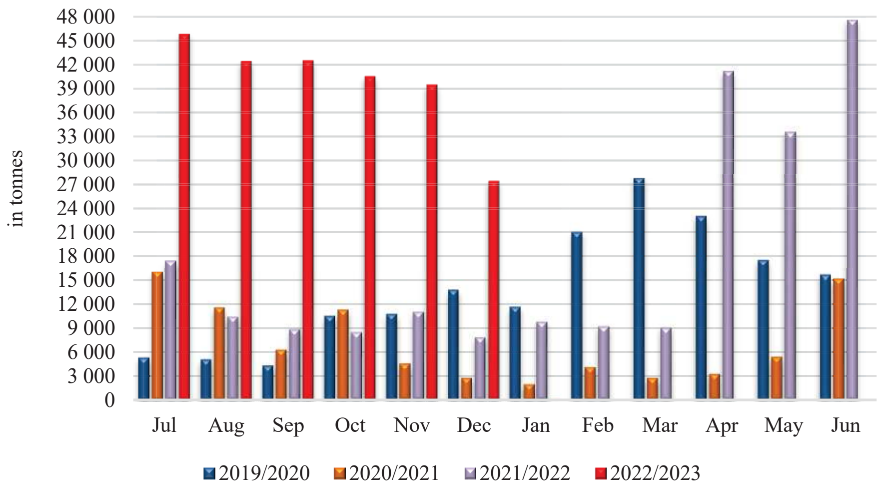


Fig. 8. Imports sunflower oil through Poland from Ukraine (in tons)

Source: Authors' own study based on European Commission data.

What may seem surprising is the significant increase in sunflower oil imports by Poland between July 2021 and December 2022. During this period, Poland imported almost four times more sunflower oil from Ukraine than in the corresponding months of the previous year and almost twice as much as in the same period in 2019/2020 (Figure 8). The situation changed dramatically in January 2023, when this import was over 300 times lower than the average from the previous three marketing years.

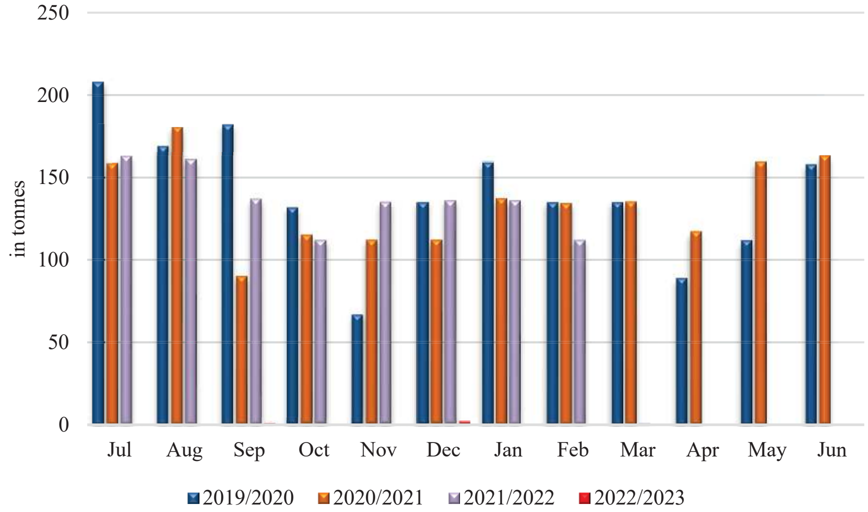


Fig. 8. Rapeseed oil exports via Poland to Ukraine (in tons)

Source: Authors' own study based on European Commission data.

Although Poland imports rapeseed oil from Ukraine, it also exports rapeseed oil to Ukraine. The marketing years 2019/2020-2020/2021 fluctuated around 1,600 - 1,700 tons. Since March 2022, this export has fallen to zero.

Conclusions

As the data analysis indicates, palm oil production has had the most significant importance in the global production of edible oils in recent years. In the marketing years 2021/22, it reached the level of 77.64 million tons and was thus 17.54 million tons higher than in the case of soybean oil, which ranked second in the world ranking of vegetable oil production. Rapeseed oil production ranked third.

The current crude rapeseed oil production scale ranks Poland third in the European Union and sixth in the world (the country's share in EU rapeseed oil production is about 13%). As suggested by the above data, despite the dynamic development of rapeseed production and processing, Poland has low self-sufficiency in producing vegetable oils (approx. 57-64%). It, therefore, remains a permanent, sizeable net importer of them. In 2015-2022, the Polish export of vegetable oils was characterized by significant variability in individual years. This export mainly concerned rapeseed oil. The situation related to the import of vegetable oils was different, with an upward trend visible in the years 2015-2022. The analysis showed that from the 2019/2020 marketing year, the import of edible oils to the EU and Poland from Ukraine had been gradually increasing. This trend was disrupted by the outbreak of war in Ukraine, which caused a decrease in the production of oilseeds and, consequently, a decline in exports. Therefore, in recent months, Poland and the EU have seen a noticeable decline in imports of vegetable oils from Ukraine. It is estimated that in the coming months, the level of imports of rapeseed oil to Poland and the EU from Ukraine will continue to decrease. It should be mentioned that the war in Ukraine and the resulting decline in agricultural production in this area may deepen this phenomenon. Consequently, this may translate into a decrease in rapeseed and sunflower oil inventories in European countries and, consequently, an increase in prices. Given the recent shocks in the agricultural products market (COVID-19, war in Ukraine, drought, embargo on grain exports from Russia, rising inflation), a problematic situation on the food market can be expected soon (Franc-Dąbrowska and Drejerska 2022) which may be particularly visible in the case of products where Ukraine is an essential player on the international arena.

It should be noted that the Ukrainian market also plays a vital role in the import of three main vegetable edible oils through Poland. According to the data of the European Commission, in the last five years, on average, almost 90% of the three oils imported by Poland (sunflower oil, rapeseed oil, soybean oil) came from Ukraine. Therefore, it is not difficult to conclude that the disruption in the production and, thus, the export of Ukrainian edible oils has a significant impact on the Polish market. It should be noted that this situation may deepen in the coming months due to the fact that domestic agricultural producers are struggling with difficulties related to the increase in production costs, which in turn may translate into an increase in the prices of raw materials for the production of edible vegetable oils.

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