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Bridging Knowledges and Practice: Understanding how Mangrove Swamp Rice Farmers Predict the Tides in Guinea-Bissau

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Abstract

We advance understanding on the relationship between smallholder farmers' practices and their knowledge on the environment through a case study of the water management of mangrove swamp rice (MSR) farming in Guinea-Bissau. In a theoretical framework of practice epistemologies and bridging ontologies we analyse how MSR farmers' understanding of tides shapes their water management practices in relation to local and scientific knowledge. Our findings show that MSR farmers have a holistic understanding of the tides and other environmental factors affecting the tides such as wind. We argue that the farmers' understanding of the environment as well as their practices are often tacit in nature. Moreover, their water management practices involve constant adaptation and sometimes improvisation, responding to socio-economic and environmental dynamics. Lastly, we argue that knowledge and practice are mutually embedded and that scientific and local knowledge can be bridged if we move away from the strict dichotomy and instead look into the multiple forms that knowledge may take.

Keywords Local knowledge and/ practice · Smallholder farming · Mangrove swamp rice (MSR) · Tides · Guinea-Bissau

Introduction

Situating local knowledge has been in debate for decades, but with the “ontological turn” in political ecology (Escobar, 2018), the discussion has been directed towards the “pluriverse”, where scientific and indigenous knowledge are regarded as fundamentally different and also lead to different outcomes. This article describes a case study on knowledge of farmers in Guinea-Bissau mangrove swamp rice (MSR) system. In this system, the local knowledge of tides is indispensable for building and maintaining dikes to protect the rice fields. Without knowledge on the tides, the MSR system could not function, as dikes built with enormous labour mobilisation would be washed away. However, the field research posed unsolvable puzzles, as the local knowledge on tides did not make any sense at first sight.

Only after lengthy and thorough ethnographic research did the link between knowledge about tides and practices of dike management become clear highlighting the enormous diversity and complexity of types of local knowledge and practices, and that bridging local and scientific knowledge can lead to mutual learning.

In the next section, we introduce our case study of water management of rice cultivated in mangrove swamps. We then present our methodological approaches utilising a mix of qualitative and quantitative methods for both data collection and analysis and address the complex relationship between the Bissau-Guinean smallholder farmers and the mangrove estuary through water management. After we analyse the diverse knowledges on how to predict tides and related water management practices. We conclude with reflections on situating local knowledge and what it means to take local knowledge seriously for the livelihood of MSR farmers.

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Background

Guinea-Bissau is situated along the Upper Guinea coast bordered by Senegal, Guinea, and the Atlantic Ocean (Fig. 1). It has a total land area of approximately 36,125 km² of which

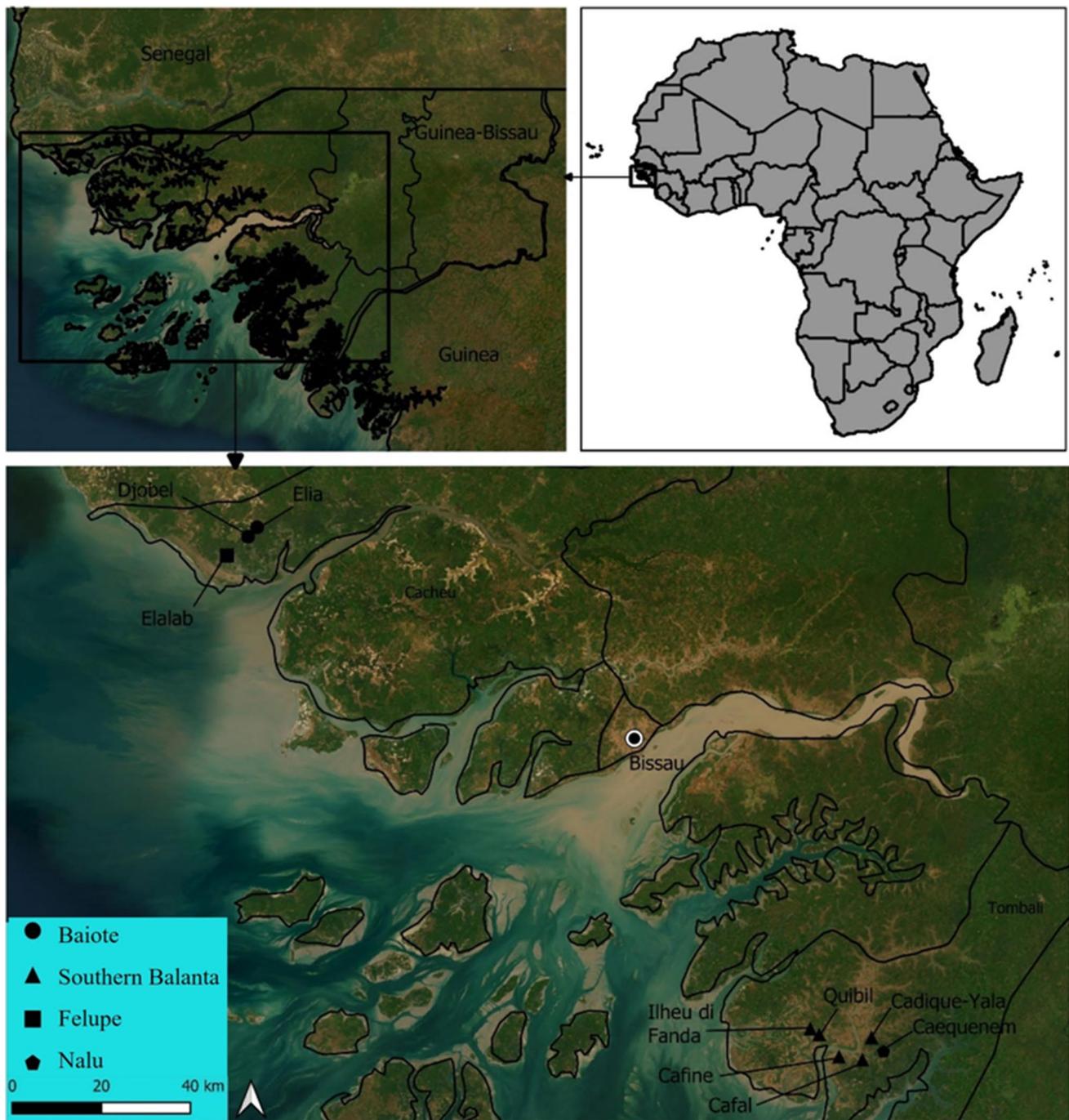


Fig. 1 Location of the villages and the ethnic groups the key informants identify with

9% is covered with mangroves – the highest ratio of mangrove area over total land area in the world. The mangrove ecosystem is a central source of smallholder rice farming livelihoods (Temudo & Abrantes, 2013).

Mangrove rice fields (*bolanhas* in Guinea-Bissau Kriol, kl) are located within the intertidal zone and dams and dikes are built to protect them from inundation with sea and estuary water. Tides in Guinea-Bissau are semi-diurnal, i.e., with

two occurrences of high water (HW) and two of low water (LW) each day.¹ MSR is a rainfed system that relies on an even distribution of rainfall throughout the rainy season. Annual rainfall varies according to latitude, from 1000 mm

¹ HW is the maximum height of a rising tide while LW is the minimum height of a falling tide.

in the northern part of the country up to 2500 mm in the south (Mendes & Fragoso, 2023). The rainy season starts late May and lasts until early November with prevailing winds coming from the west, southwest and south. The dry season lasts from November until May with the prevailing winds coming from the north and northeast. Water management in MSR farming requires intensive manual labour for tilling, transplanting, and building and maintaining dikes, and knowledge of the tides (Sousa & Luz, 2018; Temudo, 2018).

These activities include the construction, maintenance and repair of dikes to reclaim land from the mangrove forest. For dike construction, farmers cut soil into cubes that they transfer to the dike's location using an iron-tipped wooden spade. Soil is added until the desired height (height can range from 0.3 to 1 m) is reached. For dike maintenance, farmers raise the dikes every 3–5 years depending on the dike's height and location or as needed (e.g., in case of overflow). Some locations require greater height and/or width and more frequent maintenance. Factors affecting this include (but are not limited to) soil texture, elevation/topography, proximity to the river, and mangroves' genus (*Avicennia sp.* or *Rhizophora sp.*) and presence outside of the dike. Farmers repair any dike holes or ruptures. Holes can vary in size and are usually caused by some crustaceans and reptiles taking advantage of poorly compressed soils or organic matter such as roots and branches. Dike ruptures have serious consequences as estuary water inundating the rice field could result in harvest loss and lead to the formation of gullies in the paddies, rendering them unusable. Farmers report this as a major problem in MSR farming (Temudo et al., 2022).

Recent research has identified changing social and environmental issues that are increasing problems for MSR farmers, such as dike ruptures (Davidson, 2016; Temudo et al., 2022; Temudo & Cabral, 2023), including changing crop preferences, e.g., cashew, increased labour costs, decreasing mutual aid, urban migration, decreasing precipitation, changing precipitation distribution, and rising sea levels. Increased HW and current cause estuary water to overflow dikes and increase erosion leading to ruptures. While the crucial role of tides in the water management is clear (Sousa & Luz, 2018; Temudo et al., 2022; Temudo & Cabral, 2023), how MSR farmers' understanding of the tides is related to their water management practices remains unclear.²

² Sousa and Luz (2018) discuss this gap. However, our findings do not agree with their conclusions.

Methodology

The first author (FA) and the third (TA) used qualitative and quantitative methods for data collection and analysis to study the MSR farmers' practices and knowledge. The FA conducted 18 months of fieldwork in 2021–2023 (4 months in 2021, 8 months in 2022, and 6 months in 2023). He is from the Philippines with an agricultural and water resources engineering background specialising in hydrologic modelling. In January 2021 he began his PhD fieldwork in Guinea-Bissau with an initial idea to set-up a hydrologic measurement program to develop quantitative models of MSR farmers' water management system. However, after two months he realised that MSR farmers' diverse and complex water management practices could not be captured by a purely objectivist approach, and turned to ethnographic methods including informal one-to-one and group conversations, unstructured and semi-structured interviews, and participant observation to investigate farmers' knowledge of tides and factors affecting the tides in relation to their water management practices.³ The FA, as well as the TA, conducted all communication in Kriol.⁴ From his base in two villages, Cafine (Tombali Region, southern Guinea-Bissau) and Djobel (Cacheu Region, northern Guinea-Bissau) (Fig. 1) he occasionally visited seven other villages⁵ for triangulation. The FA kept a daily record of his observations of the farmers' practices and of the environment and own reflections. Quantitative methods included measurement of the tides in Cafine and Djobel from July 2022 to June 2023 using pressure-based water level sensors installed just outside of the dike. The TA conducted long-term ethnographic fieldwork on the MSR system for a total of 90 months between 1990 and 2023 and conducted cross-checking interviews on the FA's initial findings between 2022 and 2023.

We used field notes to construct a narrative of the farmers' experiences with and understanding of the tides and their relation to water management practices. The measurements were used to gain a better understanding of the practices in relation to the bio-physical system. From the constructed narrative of practices, we identified the different types of knowledge found in academic literature on smallholder farming such as performance (Richards, 1993), local ecological knowledge (Berkes et al., 2000), and tacit knowledge (Ingram, 2008).

³ This study does not include the social-organisational and gender dimensions of the farmers' knowledge and practices related to the water management system.

⁴ Kriol is the country's lingua franca. However, each group has its ethnic language.

⁵ Elalab and Elia in Cacheu; Cafal, Cadique-Yala, Caequenem, Ilheu di Fanda and Quibil in Tombali.

Fig. 2 The lunar calendar used to consult the MSR rice farmers to determine suitable dates for dike building. Based on the Moon phase models (www.timeanddate.com), we approximated the Moon phase for each day of the month



Moon, Tides, and Water Management by MSR Farmers

In February 2022, the Malmon project (www.malmon-desira.com) conducted a participatory action research (PAR) activity where we brought MSR farmers from different ethno-linguistic groups to build a dike together in Djobel village⁶ located within the inter-tidal zone. It was fundamental that the activity was conducted in a period where the tidal conditions were favourable for dike building, when there is relatively lower HW and weaker estuary current during the rising and falling tides. The FA made a lunar calendar to consult with Balanta *enjenherus*⁷ and Djobel villagers to determine the suitable dates for dike building (Fig. 2), based on Sousa and Luz's (2018) description of MSR farmers' local knowledge that designates Day 1 as starting on the second day after the first sighting of the crescent Moon after the new Moon and lasts 29 or 30 days. Sousa and Luz describe how a Nalu MSR farmer highly regarded in his village as knowledgeable and skilled in dam and dike construction used this calendar during a construction project in a village in Tombali,⁸ and underline its importance in planning

dike- and dam-related activities in a way that makes implicit that this is general knowledge among MSR farmers.

The FA travelled to the Tombali region of southern Guinea-Bissau to consult *enjenherus* in Caequenem (1), Cadique (3), Quibil (1), Cafine (5) and Cafal (1), of whom only one, a Nalu *enjenheru* who learned dam and dike construction techniques from two Balanta *enjenheru* and the behaviour of the tides from one of them, was able to recommend dates (see Sousa & Luz, 2018): 6–10 or 21–25 February 2022. While the Nalu *enjenheru* easily understood the lunar calendar, the others had difficulties and commented that they do not use that kind of calendar. The FA then consulted the elders in Djobel, who, after he explained the lunar calendar a couple of times, said they understood the calendar and selected the dates 15–19 February. On the premise that the Djobel villagers are most familiar with their environment (including the tides) we selected with the dates recommended by the elders. The day before the activity, after our arrival with the Nalu specialist and two Balanta farmers, the Djobel villagers warned us that the spring tides were “still coming with force” and the conditions were therefore less suitable for dike building. We decided to proceed because the Nalu and Balanta farmers had travelled 400+ km to Djobel (a logistical nightmare in Guinea-Bissau).⁹ Afterwards we held a meeting with the Djobel elders to understand what had happened. They told us that they did not understand the

⁶ The authors are part of the Malmon project but with different positions. The FA and TA participated in the PAR activity.

⁷ *Enjenherus* (kl, engineers), as they call themselves and are called by other farmers who recognise their expertise, are MSR farmers who have a reputation as dike and dam specialists in Tombali and Quinara.

⁸ The authors used a pseudonym for the village, but we were able to identify the Nalu farmer and village in question.

⁹ What transpired in this activity is outside our scope here and will be addressed in a future article.

calendar and felt pressured to pick the dates, as the activity would benefit their village.

After this activity, we asked: Why was only one *enjenheru* able to predict the tides? There is a very clear relation between the phases of the Moon and the tides. In rural Guinea-Bissau, the Moon has a highly visible presence at night. Looking at the Moon phases would allow planning of dike management well ahead of time and avoiding wasted investment in many days of hard labour. It was very bewildering to find out that MSR farmers do not use the lunar calendar. So, the question became why was only one *enjenheru* able to predict the tides and if MSR farmers do not use the lunar calendar: as something crucial to their livelihood, how do they predict the tides?

Tide Classifications

The FA conducted interviews in March and early April 2022 to understand how the farmers predict the tides, including questions such as “Do you know what the tides are (or would be like) today?”, “How do you know if the tides are coming with force?”, “How do you know when the tides are good for dike building or maintenance?”. The farmers were puzzled with the questions and responded along the lines of “We live near/next to the water; we just know.” While most farmers did not provide concrete responses, some provided explanations that the FA did not understand. For months, he felt frustrated with himself for being confronted with farmers’ logic and knowledge, which were seemingly beyond his intellectual capacities.

In the rainy season of 2022, the FA was in the villages of Elalab and Djobel during the full Moon spring tide of August and in Cafine in September. On both occasions, rice growing-related activities such as tilling stopped because the tides were “coming with force.” In Elalab and Djobel, estuary water flowed over the dikes and in Elalab, multiple sections broke (Fig. 3.1) resulting in the inundation of some rice fields. Farmers reacted to the overflow by constructing a thin layer of soil ridge (kl, *oriquezinho*, little dike) on the outer portion of the dike to stop or prevent overflow (Fig. 3.2). In Elalab, the villagers repaired some dike ruptures a week later during neap tides. There was no harvest loss since it was early in the rice-growing season and, in August, the salinity of the estuary water is still relatively low due to the freshwater runoff from upstream. Meanwhile, in Cafine in September, farmers went to the dikes early in the morning to construct *oriquezinho*, which they called *dubida* (kl, doubt) because “We do not trust the tides” (Fig. 3.3). For three consecutive days, the FA joined some farmers at the dikes to await the HW. Once farmers believed the tidal threat was over, they returned to their rice-growing activities. The MSR farmers pointed out to the FA the natural signs they observe. The FA saw and felt how important the tides are for them and how crucial accurate prediction is to anticipate the tides and what is at stake in case of dike ruptures.

MSR farmers distinguish the tides on different temporal scales such as daily, bi-weekly, monthly, seasonal, and yearly cycles. For daily cycles, they distinguish between daytime and nighttime HW. For bi-weekly and monthly cycles, there are two spring tides each month and each spring tide is followed by a neap tide. For seasonal cycles, daytime HW is

Fig. 3 [1] Dike rupture [photo taken during falling tide] in Elalab during the full Moon spring tide in August 2022. [2] *Oriquezinho* in Djobel. [3] Farmers in Cafine observing the rising tide during the full Moon spring tide in September 2022. The *dubida* can be seen on the right portion of the dike’s surface. [All photos taken by the FA]



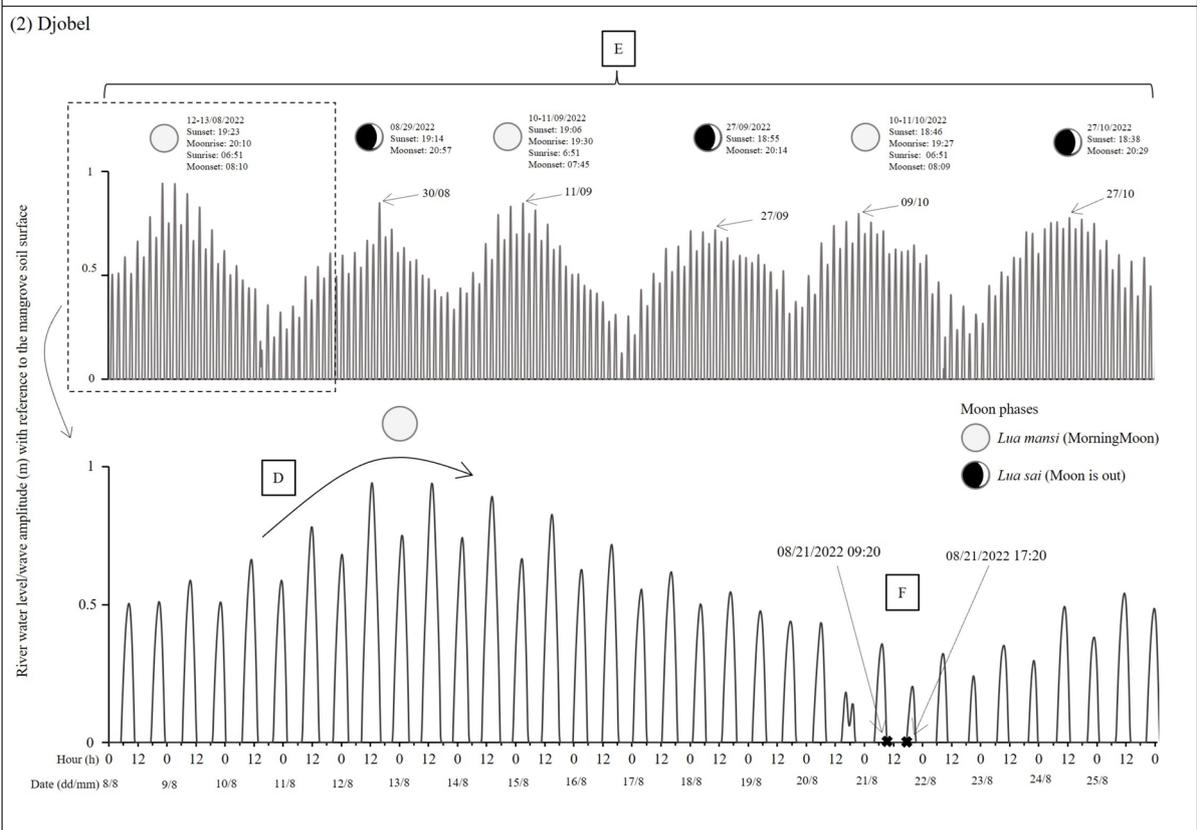
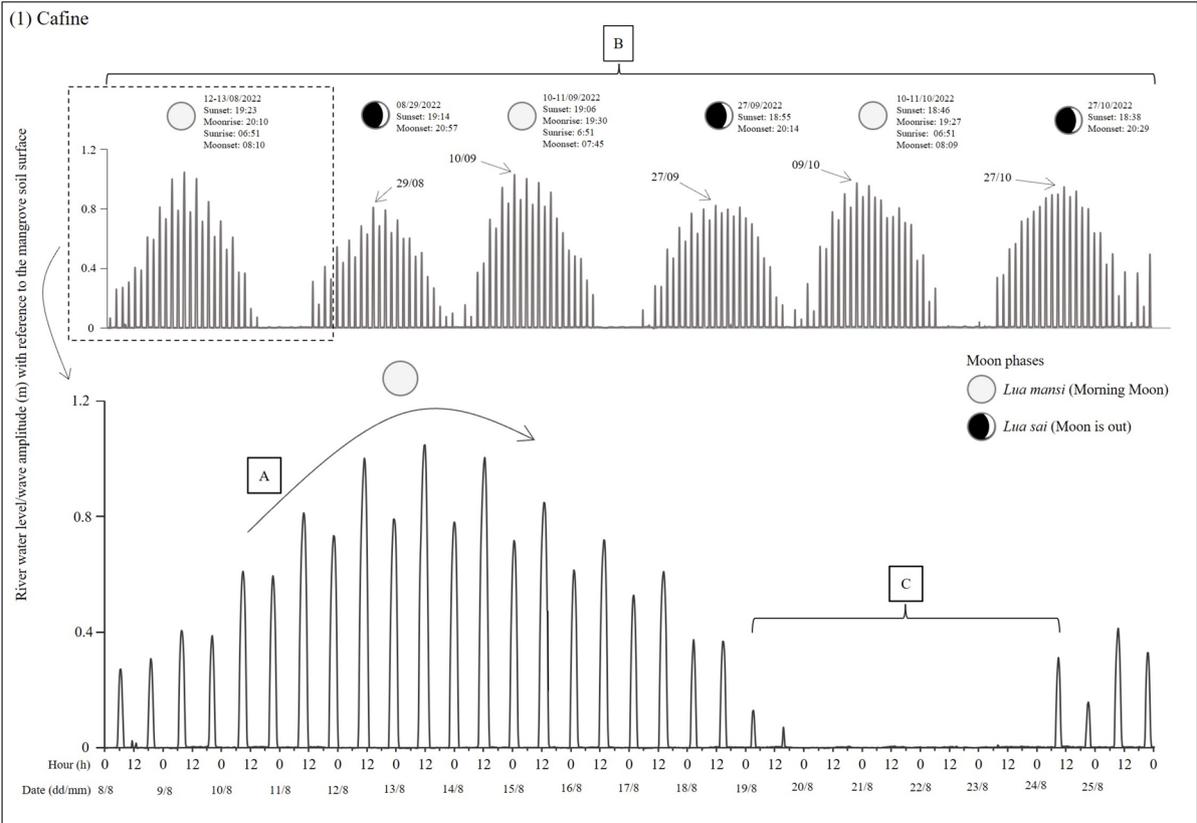


Fig. 4 Semi-diurnal tidal charts superimposed with *lua mansi* and *lua sai* from August to October 2022 based on the measurements in Cafine [4.1] and Djobel [4.2]. [A] The day-to-day behaviour of the ‘daytime’ HW increases until it reaches a peak; then it begins to decrease. [B] Farmers use *lua mansi* and *lua sai* as markers to predict when the spring tide will “lose its force”. [C] Farmers in Cafine and other villages in Tombali experience a couple of days during neap tides when relatively high-lying mangrove areas are not inundated during HW. [D] Same as (A) [E] Same as (B) [F] An example of the time window when Djobel farmers can work on dikes, after the falling tide exposes the soil until the rising tide inundates it

higher than nighttime HW from June to October and the contrary for the rest of the year. In addition, spring tides are stronger during the dry season in March or April and during the rainy season in August and September. Lastly, for yearly cycles, ‘extreme’ HW during spring tides used to occur every 5–6 years and can be catastrophic resulting in harvest loss if they occur at a crucial period in the rice-growing season.¹⁰ However, farmers state that this period is becoming more variable and has been occurring more frequently in recent years.

Predicting the Spring Tides

Southern Balanta and Baiote farmers predict the spring tides by observing natural signs such as strength of the river/estuary current, time and day-to-day behaviour of HW, presence and direction of wind, HW marks on the dikes and mangroves, amount of rainfall in the past days/weeks, and shape of the Moon at a particular position and time. For the estuary/river current strength, farmers observe the speed of the water flow. Fast water could increase the risk of erosion on the dikes. For time of occurrence of HW, they mark the time intervals between HW and LW. For example, HW occurs one hour later each day. The winds of concern are those coming from where the Sun sets (west). The farmers determine direction by sensing the wind on their skin and/or observing movement of the mangrove branches and leaves and grasses (e.g., rice). Strong winds coming from the west can induce wave formation, since the tides come from the Atlantic Ocean. Strong winds and waves can increase the dike erosion while waves increase the risk of flow over the dikes. Farmers observe the day-to-day level of the HW by directly observing the HW during slack tide and/or by looking at the HW marks on the dikes. Southern Balanta farmers mark the spring tide HW by putting a stick on the dike during slack tide or by scarring the trunk of a mangrove tree

¹⁰ During the spring tides of October 2020, extreme HW paired with heavy rain caused multiple dike ruptures in Cafine, Cafal, and Quibil, which resulted in widespread harvest loss.

with a machete, while Baiote farmers observe HW marks on the dikes and mangroves. An elder in Cafine explained:

The spring tides behave like the fingers. When the spring tides come, the water rise each day (pointing from the little finger to the middle finger) until it reaches a peak (middle finger) then it starts to go down. (4 April 2023)

During spring tides, day-to-day HW level increases (Fig. 4.1 and 4.2). Once the peak is reached it is assumed that the tides no longer pose a threat to the dikes. However, the tides have behaved erratically in recent years. When the HW spring tides coincide with heavy rains (especially August and September), farmers are not able to monitor the tides, but they check their dikes after as heavy rains, along with heavy winds and waves, increase the risks of ruptures. To have an idea when the spring tides’ force would end, farmers refer to the Moon (although not the Western lunar calendar).

Looking at the Moon

While Southern Balanta and Baiote farmers do not use a lunar calendar, this does not mean they do not look at the Moon to predict the tides. Then, the next mystery for the FA was: how do they look at the Moon? The FA asked farmers if the Moon conforms with the tides (and vice versa) using the Moon phases in Kriol as a guide: *lua murri* (new Moon), *lua novo* (waxing crescent Moon) and *lua intchi* (full Moon). Both farmer groups said the Moon conforms with the tides. When asked to explain, they pointed to the sky from west to east, explaining this was how the Moon moved and how this was related to the tides. No one used the Moon phases in Kriol. The FA did not understand these explanations about the Moon because these contrast with what he knows that the Moon, like the Sun, rises in the east and sets in the west. Consequently, he did not understand their explanation about the tides. This confused him to a point that he doubted his reality for a moment. On one afternoon in September 2022, while drinking tea with three elders in Cafal, they explained to him how the Moon’s movement is related to the tides. They pointed to the sky as they explained:

The Moon goes to the opposite direction of the Sun, it comes out there (pointing to the west) and disappears there (pointing to the east), then the Sun brings it (the Moon) back (to the west). (3 September 2022)

Asked if they were sure, they said yes. Immediately after the tea session, the FA verified on the internet that the Moon rises and sets in the east and west, respectively. That night, he also observed how the Moon moved in the sky – it moved from east to west. Two things puzzled him. First, why was no one using the Kriol terms and, second, why did they say

Table 1 Descriptions of the two Moon phases that are in common in the Balanta and Baiote languages

Moon phases ^a	<i>Lua sai</i> (kl. Moon is out)	<i>Lua mansi</i> (kl. morning Moon)
Description	When you see the Moon a few days after it has disappeared. It is very small and is visible above the western horizon after sunset.	When you see the round Moon appear on the eastern horizon around after sunset. OR When you wake at dawn and see the round Moon above the western horizon.

^aThese are Kriol terms used by MSR farmers to describe the Moon phases. Both groups have specific terms in their ethnic languages. However, within ethnic groups, there can be linguistic diversity. For example, neighbouring villages Djobel and Elia use different words for *lua mansi* and *lua sai* in Baiote language

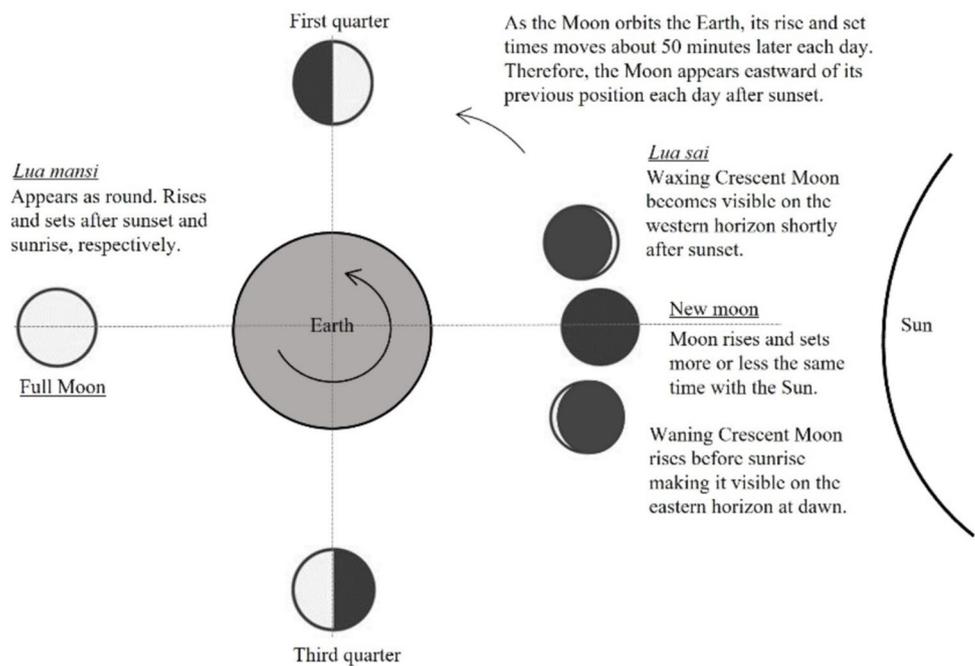
that the Moon moves from west to east? To address the first question, he asked them for the terms for Moon phases in Balanta and Baiote languages. In Balanta language, there are terms for three Moon phases while in Baiote language there are two similar terms. In Kriol, these two phases are *lua sai* (Moon is out) and *lua mansi* (morning Moon)¹¹ (Table 1). Unlike in Kriol, in which the terms refer to the Moon's shape, the terms in the Southern Balanta and Baiote languages refer not only to a Moon shape but also to a certain location in the sky and period of the day the Moon could be sighted.

Moon phases and rising and setting times depend on the Earth-Moon-Sun configuration. The Moon orbits the Earth counterclockwise for 29.5 days during which we see different parts lit by the Sun depending on its position relative to the Earth and Sun. For example, when the three are aligned with the Moon in the middle (new Moon), the Moon's surface lit by the Sun is facing away the Earth and the Moon rises and sets more or less at the same period as the Sun. Hence, during the period of a new Moon, the Moon is up although not necessarily visible, during the day and not visible at night. As the Moon orbits the Earth, its rising and setting times move about 50 min later each day and the visible surface lit by the Sun changes. After new Moon phase, Moon rise is about an hour after the sunrise although it is still not visible during daytime. After sunset, the waxing crescent Moon becomes visible on the western horizon for a brief period before it sets. Farmers refer to this phase as *lua sai* (Fig. 5). Because of its counterclockwise orbit, the Moon's rising time is about 50 min later each day, and this is what the farmers refer to as movement from west to east – that the Moon appears east of its previous position or appears to be moving eastward if its position is observed each day after the sunset. When the three bodies are again nearly aligned, with the Earth in the middle, the Moon appears round (full) and rises and sets after sunset and sunrise, respectively, the phase farmers refer to as *lua mansi*. Lastly, the waning crescent Moon (before a new Moon) rises at dawn, making it visible on the eastern horizon before sunrise, after which it will not be visible again for the next couple of days until the waxing crescent Moon appears on the western horizon after sunset. This was what the elders in Cafal meant with the Moon disappearing in the east and then the “Sun brings it (the Moon) back (to the west)”.

Southern Balanta and Baiote farmers use *lua sai* and *lua mansi* as markers of the end of the spring tides' force. When they observe *lua mansi*, this tells them that HW will peak

¹¹ The third Moon phase in Balanta language is described as the dying Moon, when you wake up at dawn and see the very small Moon on the eastern horizon. After this, the Moon will not be visible for a few days until it appears again on the western horizon right after sunset. For *lua mansi*, see Sousa et al. (2021).

Fig. 5 *Lua sai* and *lua mansi* in relation to the Earth-Sun-Moon configuration as seen in Guinea-Bissau



on the day they observe the Moon in the morning (A and D Fig. 4). While some farmers check their dikes until HW starts to go down, others may stop after seeing *lua mansi*. However, this marker may not always be reliable, as HW can increase even the day after *lua mansi*. This was the case in Cafal in the full Moon spring tides of September 2023. Farmers, except for an *enjenheru*, stopped going to the dikes the day after seeing *lua mansi* and the HW peaked the next day, causing overflow and rupture along the dikes and inundation in some *bolanhas* (including the *enjenheru*'s). For *lua sai*, this signifies that the peak HW has already passed (if the HW occurred during daytime). However, for the rainy season, the farmers are more concerned with the full rather than the new Moon spring tides as they are “stronger.” This is also what we observed in the measurements for the months of August–October (Fig. 4.1 B and 4.2 E), that the HW during full Moon spring tides is higher. Our measurements also showed that the peak HW does not always correspond to *lua mansi* and *lua sai*.

Predicting the Neap Tides

In the dry season of 2023, having participated in our PAR exercise in Djobel in 2022, a farmer in Quibil invited the Malmon team to join him in building a dam to open a new *bolanha*. This required months of preparation for our planning and coordination. In February, the farmer said he was not able to predict the tides in advance and asked the FA to

choose the dates for April.¹² This, once again, puzzled the FA¹³: How much time in advance do they determine the specific dates for such activities? He sought four *enjenherus*, who by this time had become his good friends and had developed patience with his frequent and persistent questioning, for some clarity. He posed a hypothetical but concrete question: “Next month, I would like to build a dike and dam to open a new *bolanha*. Can you tell me the dates when I can build the dikes and dam?” All answered they could not tell the exact dates, which could only be determined during the spring tides of that month. After the peak of the spring tides has passed, they count the days (5–7 days) after which the conditions are suitable for dam and dike building. After the peak, the day-to-day HW decreases up to a period when relatively high-lying coastal plains are not inundated during HW¹⁴ (Fig. 4.1 C). It is important to determine the right period with favourable soil humidity conducive for dam and dike building. Too high humidity could make it impossible to cut the soil in cubes, transfer it, and make it firm on the dam/dike structure. Meanwhile, too low humidity can cause the soil to be either too hard to cut or stick on the spade

¹² In the end, the PAR activity was conducted in May instead of April.

¹³ Though they do not use a lunar calendar, they could – in the FA's Western lens – mark the day of the neap tides and extrapolate into the future by counting the days or weeks, since they are aware of the spring-neap tides cycle.

¹⁴ As farmers told the FA, “Towards the end of the neap tides, you can walk on the ground with your slippers on”.

Dam construction,¹⁵ specifically for Southern Balanta farmers, requires close monitoring of the HW and LW and their marks on the mangroves and riverbanks, the strength of the river current and the exact times of the HW and LW to establish when neap tides' HW are lowest and the timing of rising and falling tides. Eighty or more individuals may be needed to build a dam depending on the width and length of the river for tasks allocated according to appropriate status, age, and gender, such as: (a) cutting soil cubes (young men) at strategic locations (identified by experienced men) that will not affect the stability of the dam, (b) manually transferring the soil cubes to the dam site through a human chain (young men, boys, women, and girls), (c) compressing the soil (experienced men), (d) gathering (young boys) and placing mangrove branches and rice hay on the dam's cross-section parallel to the river bed to ensure stability during construction (experienced men), and (e) bringing food and water to the construction site to feed the work crew (women and girls). The farmer commissioning the construction is responsible for providing labour, materials, food, and water while an *enjenheru* supervises construction. Dam construction begins only when the falling tide has passed the construction site when the farmers have eight hours before the next rising tides. If they miss this moment, they could either do it the next day with a risk that tides could come with force, which could wash away the newly built dam, or delay the construction until the next neap tides.

While the Southern Balanta farmers have a couple of days when the estuary water does not inundate some part of the mangrove areas during neap tides HW, farmers in the Baiote villages of Djobel and Elia and their neighbouring Felupe village of Elalab, are more concerned with the strength of the estuary current. Farmers said it is already safe to work on the dikes the day after the peak HW during spring tides because the tide had already "lost its force". Once the falling tide has passed the construction site, the farmers wait 1–2 h to allow natural drainage. The time they have to work on the dikes before the rising tide depends on elevation (at higher elevations there is longer time between the tides) and the tidal range (Fig. 4.2 F). However, farmers in Djobel reported a variety of responses on favourable dike work periods. An elder explained:

Here in Djobel, we face the tides every day. When you see the tide is low, you grab your spade and go to work.

¹⁵ Dam building is a tedious task that involves multiple steps, such as preparing the dam's skeletal structural (with mangrove trunks), dividing the dam's cross-section perpendicular to the water flow into at least five parts (depending on the width of the river/creek), filling each part starting with the sides and leaving the middle part for the last step. Closing the middle section is the most crucial and is what we refer to here as 'dam construction'.

Meanwhile, a young farmer said he prefers to work in the morning:

It is best to work in the morning because the Sun is still not hot. I go to work early in the morning when it is low tide, and I stop when the high tides come and the Sun becomes too hot. (31 May 2023)

Multiple Types of Knowledge

Our findings show that farmers have extensive local environmental knowledge that enables them to identify the timing and strength of daily, bi-weekly, monthly, seasonal, and annual tidal cycles. This shows the extensiveness and holism of farmers' environmental knowledge (Berkes & Berkes, 2009). A similar example is Polynesian navigation of the Western Pacific by reading natural signs such as locations and movements of celestial bodies, ocean swells, presence and direction of wind, and presence of clouds and fauna (Finney, 1994). We argue that MSR farmers use mental models to predict the tides a few hours or days ahead based on observations, knowledge on the regularities (at different temporal scales) and other local environmental factors that affect the tides such as the wind, current and the Moon. However, these processes remain based on tacit knowledge hard to articulate or express in propositional form (Polanyi, 1958) that is derived from experience, intuition, conveyed personal interaction through shared experiences (Morgan & Murdoch, 2000) and a form of embodied knowledge and practice or *habitus* (Bourdieu, 1990). That MSR farmers' water management practices are tacit knowledge became apparent when they had difficulty explaining how they predict the tides, as they answered along the line of "we just know". The FA began to understand when he participated in monitoring the dikes during the full Moon spring tides HW in August and September 2022, when the farmers pointed out the natural signs they read.

While we can identify the natural signs and the regularities farmers observe, how they are operationalised into predictions remains unclear and tacit. As we have stated previously, we believe farmers use mental models to predict the tides, which rely on sensory and cognitive processes. Our findings agree with Simon's findings (2023) among Wayuu free-diving fishers in Manuare, Colombia, who feel their environment and use terrestrial landmarks to accurately find unmarked underwater traps and navigate underwater, while the actual processing and operationalisation of their observations remain tacit and form part of 'marine sense' (ibid.). We refer to these processes as 'know-how'.

Lundvall and Johnson (1994) propose four types of knowledge: *know-what* (facts), *know-why* (e.g., principles), *know-who* (who knows what and can do what), and *know-how* (skills). Using this framework in our case study,

farmers' knowledge on tidal cycles is *know-what*, their knowledge on effects of winds on tides (wave formation) is *know-why*, their knowledge of individuals' dams building expertise (e.g., *enjenherus*) is *know-who*, and their skills in predicting tides and building dikes and dams is *know-how*. We argue that *know-what*, *know-why*, and *know-who* can be expressed in propositional form while *know-how* is in tacit form.

However, this typology does not fully capture the complexity of MSR farmers' knowledge such as when soil moisture is favourable for dike building or timing dam building according to favourable tides. We therefore add a fifth type *know-when*, first used by (Hulme, 2014) to refer to the "rules of engagement in the implementation of research" in relation to the importance of examining the different forms of knowledge to facilitate exchange between scientist and practitioners. While Hulme's conceptualisation addresses the challenges in knowledge exchange, it does not relate to time, whereas our re-conceptualisation in our case study is broad, denotes time, and is in line with Lundvall and Johnson's typology.

Thus, we use *know-when* in the sense of the ancient Greek word, *kairos*, which denotes a time when the conditions are favourable to realise a crucial action. Like *know-how*, this type of knowledge is tacit, is derived from experience, involves trial and error, and is conveyed through personal interaction and shared experiences. In MSR farming water management, *know-when* refers to farmers' and *enjenherus*' ability to identify the most favourable time and circumstances for building dikes and dams. These skills require continuous observation and extensive knowledge of the tides and the environment and a high level of skills. If the crucial moment is missed even by a few hours, it could result in the destruction of the dam and wastage of all the efforts and resources. While knowing the right moment is important in water management in MSR farming, practices involve improvisation such as repairing dikes during less favourable tidal conditions (see also Martiarena and Temudo (2023) for a broader description of farmers' knowledge and practices in MSR cultivation).

While they do not use a lunar calendar, elders in Djobel said they understood the calendar and risked selecting the wrong dates. This can be seen as a decision that would imply the use of performance (Richards, 1989, 1993; Glover, 2018), meaning that they needed to improvise during the PAR activity to serve their own agenda of repairing the dike. Performance can also be seen in other practices such as dike repairs right after a rupture and the construction of *oriquezinhos* in Elalab, Djobel and Cafine. In the case of constructing *dubidas*, this can also be seen as risk avoidance. Risk-avoidance and risk-taking practices are usually associated with tacit knowledge although they could also include performance. These involve complex factors such

as socio-economic imperatives and changing environment. Farmers know that tides can be unpredictable and our measurements in Cafine and Djobel also showed that *lua mansi* and *lua sai* sightings can be unreliable in predicting when the spring tide "loses its force" yet farmers take the risk of water overflowing the dikes and dike rupture by not going to the dikes the day after they see *lua mansi*. Farmers monitor the full Moon spring tides during August, September, and October when they undertake nursery preparation, tilling, and transplanting. The start and end of these activities depend on rainfall, and transplanting has to be completed before the rainy season ends in October. This pressure plays a part in the trade-off between labour input and risks. Another factor is the increasing unpredictability of the tides due to climate change. Farmers' local knowledge on the tides is based on continuous observations of environmental regularities. However, as sea levels rise and rainfall amount and distribution change, the regularities on which the farmers' environmental knowledge are based are changing.

In the nine study villages only one farmer in Caequenem uses a lunar calendar to predict the tides as presented by Sousa and Luz (2018). We argue that MSR farmers do not use a lunar calendar because the tides are complex and requires on-site monitoring and continuous observation. Four crucial factors that farmers observe for dam- and dike-related activities are the estuary/river current strength, daily HW behaviour, timings of HW and LW, and wind. For dam construction, knowing strength of river or estuary flow and HW behaviour is important for predicting the day neap tides are weakest. Meanwhile, the timings of the HW and LW are crucial for dike construction. For dike monitoring, current strength, HW behaviour, and wind direction and strength are crucial for predicting the peak of the spring tides, and the timings of the HW are important to determine when farmers can work on dikes. For both cases, a lunar calendar does not provide all the information they need.

While the lunar calendar does not provide this complex information, the calendar can be used to plan the activities weeks or months in advance. However, our findings that the farmers neither use a calendar nor count the interval between spring/neap tides for planning dam- and dike-related activities lead us to conclude that they do not plan ahead because they do not find the need to do so. We needed to identify the PAR activity's dates in advance to make the necessary logistical arrangements as part of our larger agenda. However, it soon became clear to us that the farmers define the precise date of their activities only one week in advance based on their tacit knowledge of local tidal conditions likely to be able to accommodate unpredictable eventualities that might impact their ability to undertake planned activities, such as health issues, ceremonies and funerals. Although they do not use a lunar calendar or explicitly say they do not look at the Moon

except for *lua mansi* and *lua sai*, we believe that, when the farmers see the Moon, they unconsciously have an idea of the tidal conditions.

Bridging Knowledges

If a researcher hears farmers explain “the Moon moves from west to east”, they might dismiss them as illogical as the explanation seems to contradict the scientific understanding of the Moon’s movement. However, if a researcher with an astronomy background hears the same explanation, he might understand them right away. These are just speculations but, with this, we point out the social interface of the divide between scientific knowledge and local knowledge (Long, 1989, 2001). We examined the difference between the FA’s scientific knowledge and the farmers’ local knowledge on three dimensions (Agrawal, 1995): (1) substantive, (2) contextual, and (3) methodological and epistemological. First, we argue that there is no difference with regard to substance since, while the knowledges about the Moon differ, the farmers’ local knowledge refer to the Moon’s movement, shape and location, which are characteristics also found in scientific knowledge. Second, the farmers’ local knowledge is rooted in context. For example, the farmers’ knowledge on Moon rise and setting times will not be applicable in other parts of the world with a different latitude or even in other villages in Guinea-Bissau because some farmers use markers such as trees to locate directions. Lastly, on the methodological and epistemological level, the farmers’ local knowledge is based on continuous observations of the Moon’s movement, shape and location, whereas scientific knowledge is fundamentally based on the mathematical calculations of the Earth-Sun-Moon configuration.

When the FA started his fieldwork, his knowledge on the Moon was trivial at best. He had no personal relationship with the Moon except at moments when he was in areas with minimal light pollution (e.g., island beaches) to marvel at the beauty of the night sky or during Super-Moon and lunar eclipses. Until the FA doubted his knowledge on the Moon, he did not use to look up in the sky and observe the Moon and its movement during his free time. As he delved into farmers’ explanations and Moon phases, he was able to make sense of the farmers’ knowledge on the Moon and relate it to scientific knowledge. Similar circumstances occurred on the FA’s attempts to understand farmers’ knowledge on tide prediction and dam- and dike-related techniques. These examples show that local and scientific knowledge can be bridged through contextualisation – situating local knowledge in their context and recognising the multiple forms in which knowledge may take.

Conclusions: Taking Local Knowledge Seriously

We have a habit of writing articles published in scientific journals to make the work as finished as possible, to cover up all the tracks, to not worry about the blind alleys on how you had the wrong idea at first and so on. Richard Feynman, Nobel Lecture at Caltech (USA), 11 December 1965.

Throughout this research we encountered several methodological challenges in both fieldwork and theorisation in understanding local practices and knowledge in the context of scientific knowledge. During fieldwork, the FA encountered explanations that did not make sense at first because of ontological differences (e.g., differences in looking at the Moon) and the tacit and embodied nature of the knowledge he was trying to understand. Understanding farmers’ explanations required lengthy and thorough ethnographic fieldwork.

During theorisation, we struggled to find a single framework on local knowledge to make sense of our empirical findings and link them to scientific knowledge. We tried to use frameworks such as performance, tacit and local ecological knowledge. However, we encountered problems, as these frameworks – used individually – were not able to explain our data. We started making sense of our data when we used multiple frameworks on knowledge (local ecological, performance, tacit, know-what/who/what/how/when) and linked these different types of knowledge to scientific knowledge by analysing them under the three dimensions proposed by Agrawal (1995).

Our study demonstrates what it means to take local knowledge seriously both in empirical and academic contributions. We aim to transform the results of this study into an infographic video of the farmers explaining their tide prediction knowledge and how to utilise this knowledge with a calendar application in smartphones, which many young farmers have. With the digital calendar, farmers would be able to systematically record their complex observations. This would aid them in coarse planning especially during the rice-growing season where dike monitoring during spring tides could coincide with time-bound agronomic activities such as ploughing and transplanting. This shows how researchers’ thorough understanding of farmers’ knowledge and practices could provide contextualised approaches and tools. Lastly, we argue that to bridge local and scientific knowledge we must move away from the strict local–scientific knowledge dichotomy and instead focus on the multiple forms that knowledge may take.

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Declarations

Competing Interests The authors declare no competing interests.

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